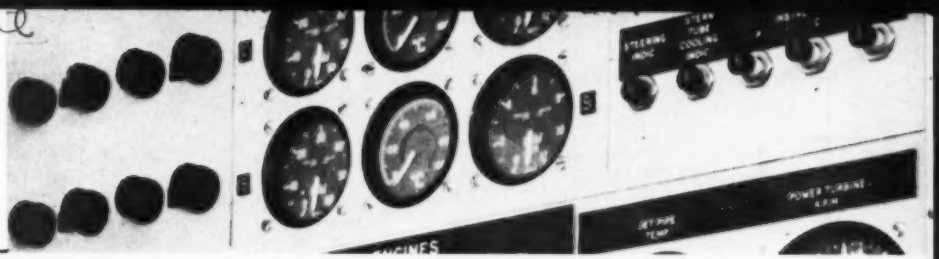
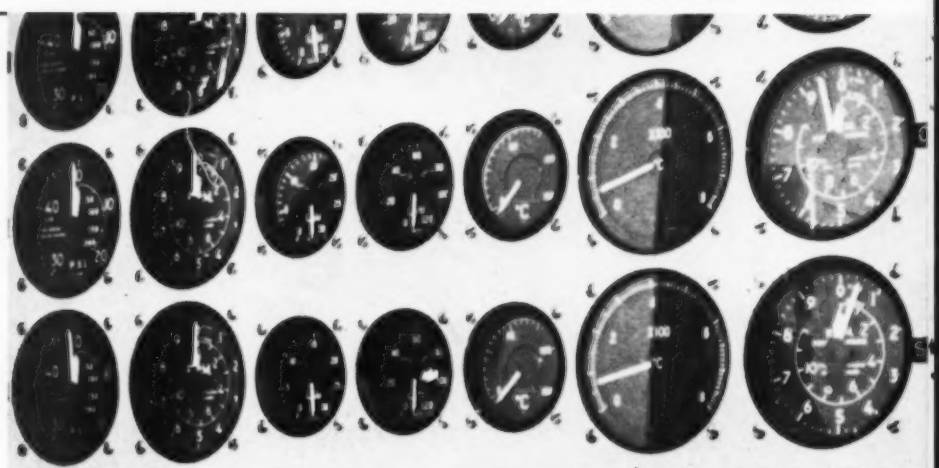
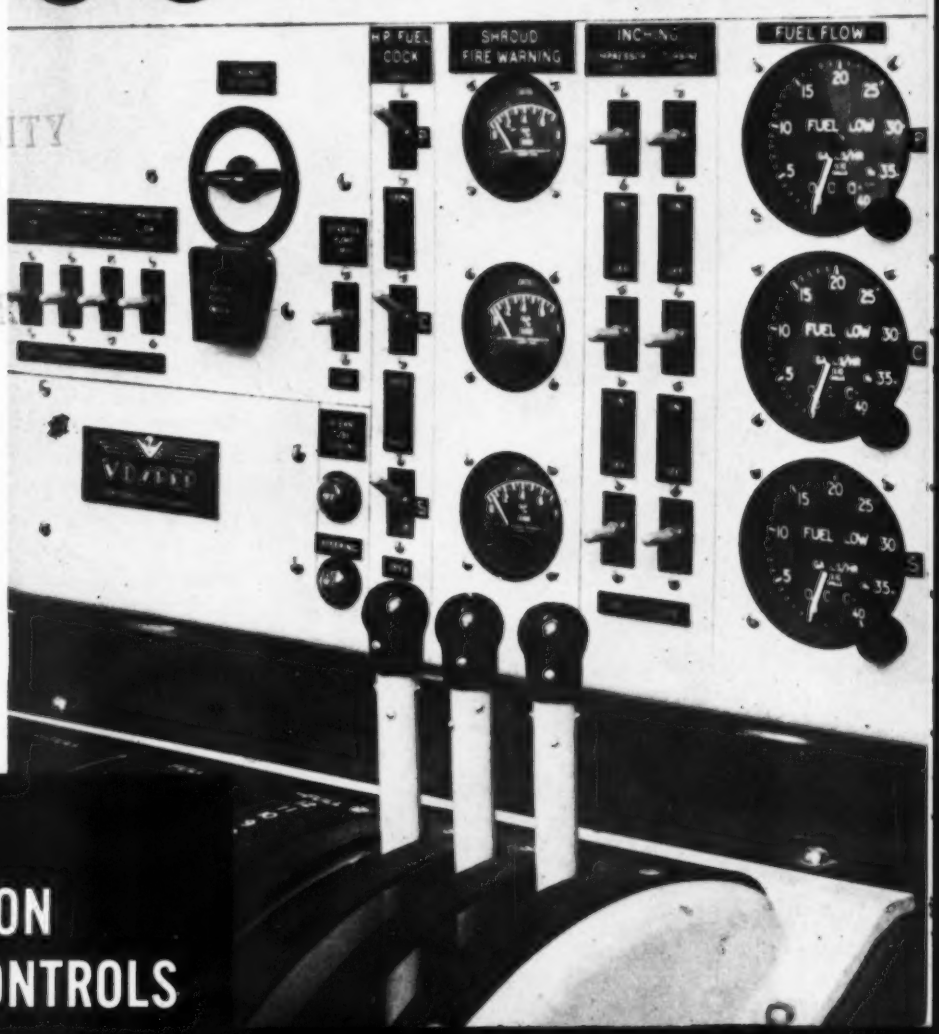
vember — December 1961

GAS TURBINE







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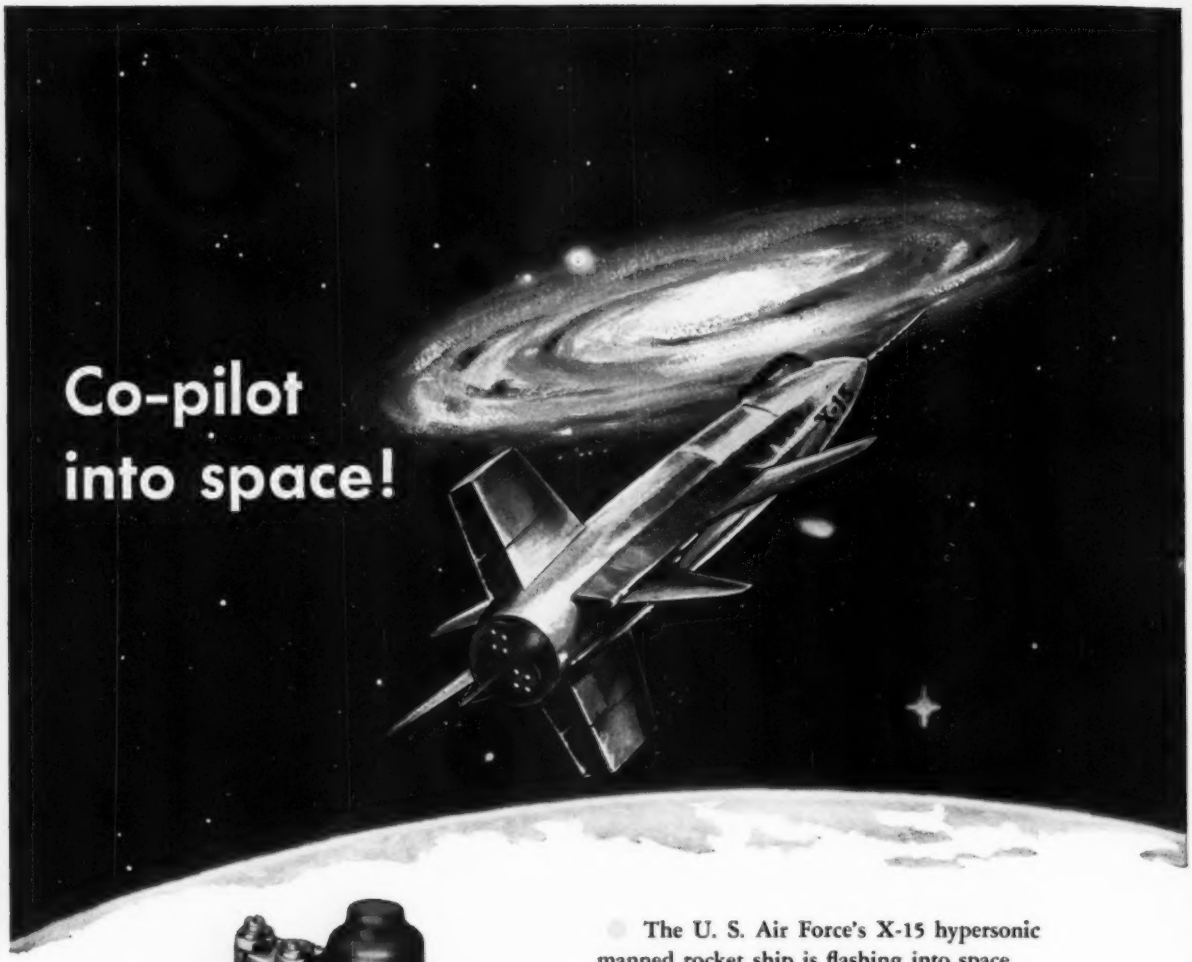
BROADENING THE SPECTRUM ON GAS TURBINE CONTROLS



The U. S. Air Force's X-15 hypersonic manned rocket ship is flashing into space with a dependable "co-pilot" on board. A Woodward variable speed governor is charged with the vital duty of controlling the speed of the fuel pumps on the Reaction Motors' XLR99 rocket engine — maintaining correct engine speed over extreme ranges of temperature, atmospheric pressures and acceleration rates.

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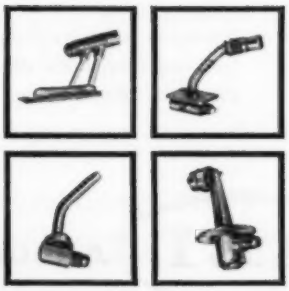

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The picture shows work on the rotor of an L21C gas turbine being built for the Basrah Petroleum Co. Larger machines of similar design —the L51C—were recently installed in Iran to supply power for the electrification of the Gach Saran oilfield.

Produced by AEI Turbine-Generator Division, Britain's largest manufacturer of turbine-generators.

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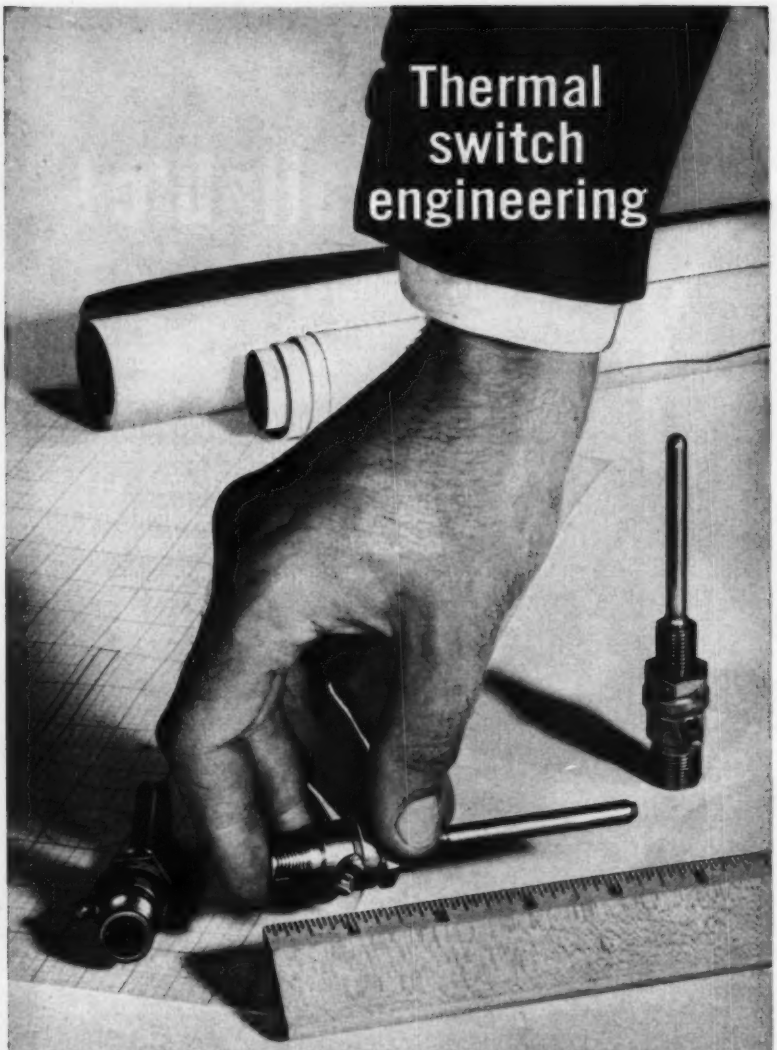

CPI RESEARCH CREATES A NEW "SHORT HEAD" SWITCH

From CPI research comes this new thermal switch with the shortest head construction of any AN connector type switch. This hermetically sealed, field adjustable, probe type switch was developed for an aircraft manufacturer to control inlet air temperature for heating and turbine exhaust temperatures for air conditioners.

There are other uses, too—controlling temperatures of gas turbines and heat exchangers or oil in gear boxes—in fact, many places where there's need for a hermetically sealed switch with a fast, easy electrical connection. It is possible that this or the many others developed by CPI specialists may not solve your problem. If not, CPI research can create the switch that will! Send your specs.

This new switch is constructed of all high temperature alloys and has a calibration range of —20F to 1750F with safe momentary overshoot to 2000F and undershoot to —100F. It is available in a variety of threaded and plate mountings. Mention "Spec-Stat" when inquiring.

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SEVENTH ANNUAL

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ANNUAL CONFERENCE of the PROCESS INDUSTRIES DIVISION of ASME Will Meet at the Same Time and Place

GAS TURBINE MAGAZINE . . . *incorporating gas turbine power*

GAS TURBINE

VOLUME 2, No. 6, November-December, 1961

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Executive Editor Len Griffing

Contributing Editors

Automotive R. Tom Sawyer
Aviation Dr. Otis E. Lancaster
Industrial J. W. Sawyer
Marine J. W. Sawyer
Nuclear F. L. Jackson
Science Alexis J. Diakoff

President James E. Jones

Publisher G. Renfrew Brighton

Circulation Fulfillment Mgr. Adele Hoppe

Production Mgr. W. B. Williamson

Art Director Leonard Wahlgren

Representation

Mid-West Frank Wenzel, Dist. Mgr.
605 N. Michigan Ave.
Chicago 1, Ill.
Rm. 206
Tel: MIchigan 2-5050

Ohio Western Pa. & Western New York C. F. (Dick) Tope
12500 Shaker Blvd.
Cleveland 20, Ohio
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Pacific Coast Pugh & Rider Associates
404 Halliburton Building
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Los Angeles 17, Calif.
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Union Pacific's new and mighty locomotive crests Sherman Hill, Wyoming, with a heavy load.

WORLD'S MOST POWERFUL LOCOMOTIVE SPEEDS FREIGHT ECONOMICALLY WITH BENDIX FUEL AND IGNITION SYSTEMS

This is the world's mightiest self-powered locomotive at work. On level track, it can pull 735 fully loaded freight cars—a train more than seven miles long! Its two engines—an auxiliary diesel engine and a gas-turbine power plant—depend on Bendix fuel injection and ignition systems to help keep its mighty power flowing smoothly and efficiently.

This new gas turbine-electric locomotive, built by General Electric for Union Pacific, is designed to haul freight faster and more economically. It burns less expensive "residual" fuel—a thick, viscous substance with a heavy tar content which must be heated before it will flow freely.

The Bendix ignition system fires this low-volatile fuel as efficiently as volatile gasoline is ignited in your automobile engine. The Bendix fuel injection system is used in the auxiliary diesel engine, which also furnishes power for "yard" movement of the locomotive.

General Electric has been an important builder of locomotives for more than 65 years. To be selected as the supplier of fuel injection and ignition equipment by G.E. for the mightiest locomotive they have ever built, is truly one of the finest tributes that could be paid to the all around efficiency of Bendix equipment.

It is equally impressive that whenever exceptional performance, complete dependability and operating economy are the requirements, diesel engine manufacturers in increasing numbers are turning to Bendix for their fuel injection and ignition requirements.

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EDITORIALLY SPEAKING

Speaking of "Packages" . . .

This is the age of packaging. Everything from a toothpaste carton to creation of a 15,000-kw peaking plant gets the full "package concept" treatment. The "appeal" factor, however, differs considerably. With the packaged power unit, concern is not so much with the "eye appeal" but rather what the integrated package will do in terms of performance, in holding maintenance down and in cutting capital costs. However, the package concept is a sign of the times; it was not always so.

Not so long ago, it was customary to buy a prime mover, then let's say a generator, select all the system components and then put the power plant together. A lot of engineering work was involved in matching components and designing the overall unit. Various skills were called upon and in many locations these were hard to find. Finally, there was always a matter of divided responsibility, particularly if warranty was involved. All these factors enhance attractiveness of the package concept . . . the turn-key unit.

The gas turbine industry has benefitted from this evolution that was a long and sometimes painful transition in other primemover industries. The user thinks in terms of completely engineered packages and designers are fulfilling the need. Yet while today we think in terms of the package, don't think for a minute that each package is the same or that there is not room for selection and specification of components.

While the integrated unit concept is valid, the controlling factor is that seldom do two "packages", even though basically of the same design, do the same thing. Also, there is the matter of experience factors with different components and even personal preferences. Otherwise, there would be only one set of suppliers and one vendor of packages.

Specification is still important. One air cleaner may look good on the basis of first cost but experience shows that long-term ownership costs favor another make. One type control may have a terrific reputation for one type of application but may not be the one for other services.

So within the highly-desirable "package" concept, there is still plenty of room for individual selection and specification. This must be understood and this customer's perogative used if we are to get the best performance and lowest long-range cost of ownership. The factor of choice will also create competition that invariably results in better, lower-cost products . . . and also help build a bigger industry.

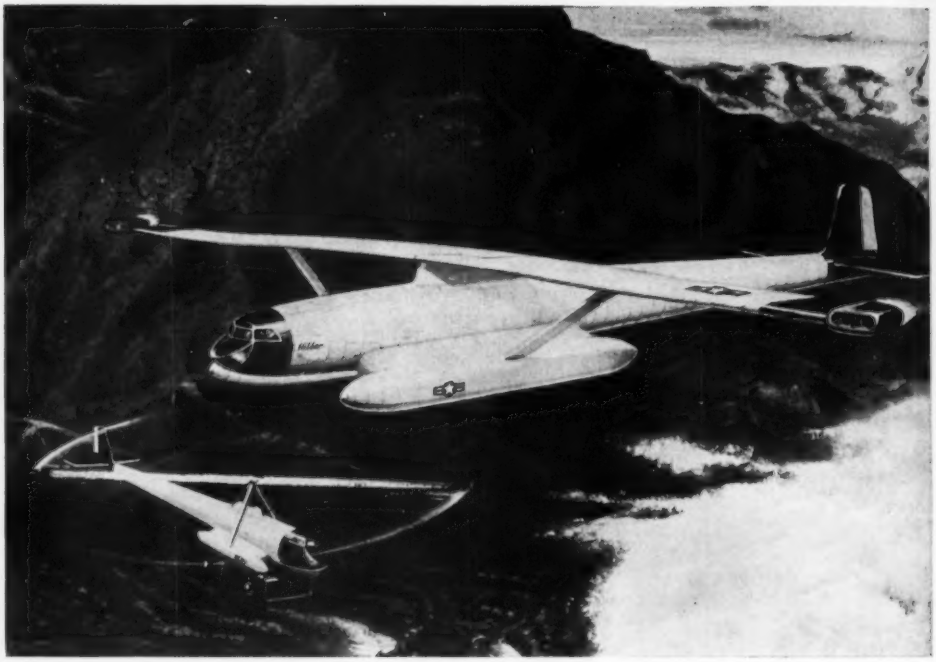
Brian P. Emerson

Your consulting editor is now in Alaska, as this issue goes to press, for the U. S. Army Transportation Materiel Command, to inspect gas turbines in arctic operations.

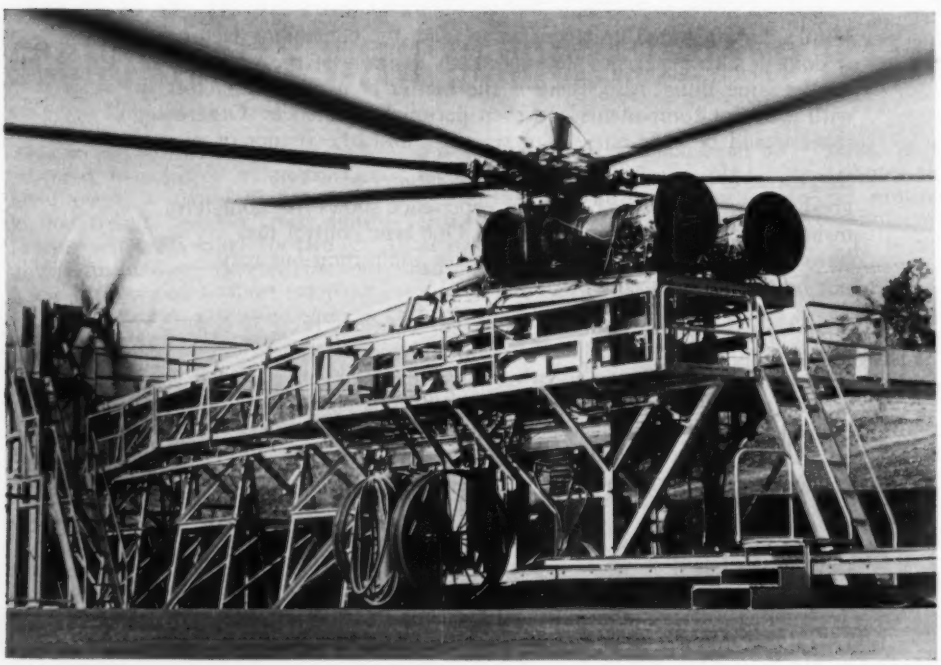
GT INDUSTRY NEWS

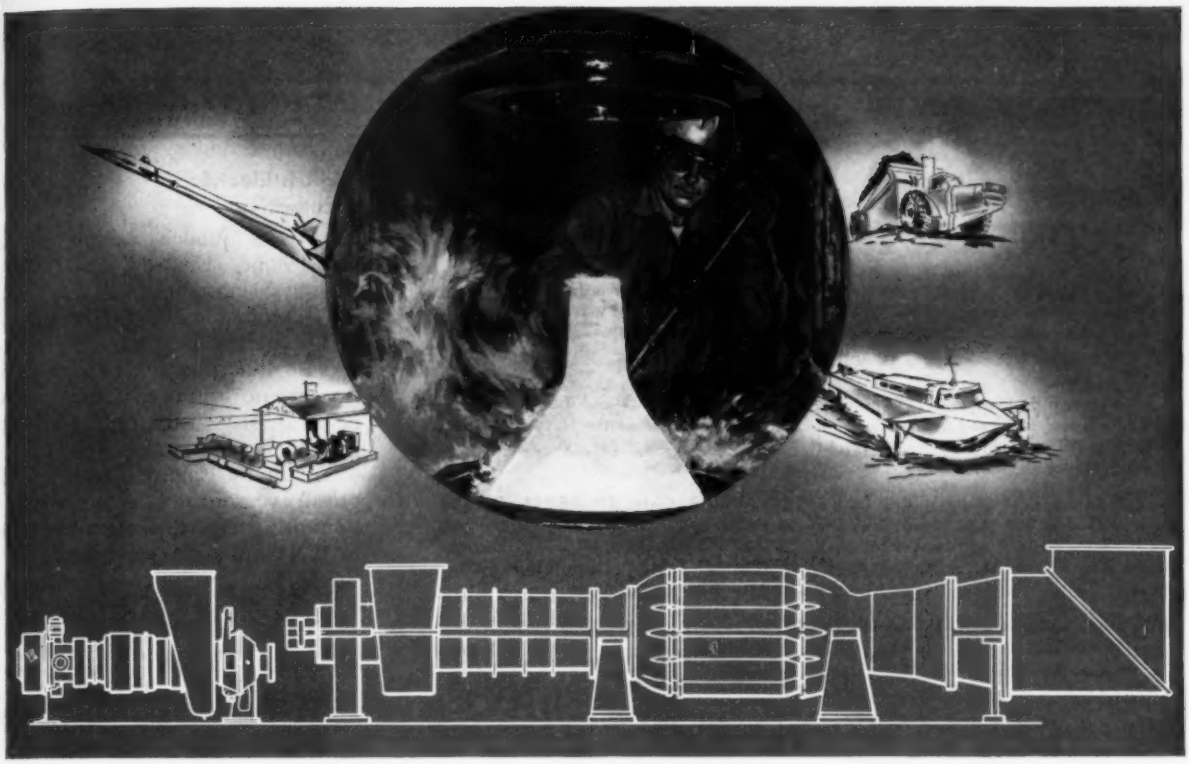
Rotors Into Wings

The Hiller STORC flying crane helicopter, powered by two turbojet engines in each rotor blade tip, would ferry itself overseas at airplane speeds. STORC can hover and operate as a helicopter (lower picture), then be landed for conversion into an airplane, with wingtip engines.



Heart of the Matter The main rotor, tail rotor, transmission system and dual turbine power plant of the Sikorsky heavy assault transport helicopter have already been operated for many hours on this special test stand at Sikorsky. Turbines are Pratt & Whitney JFTD-12 each rated 4050-hp; 870-lb.





Turbine Forgings Unlimited

Few prime power sources depend so completely on part integrity for reliable performance as the gas turbine. Its extremes of temperature, rotating speed and imposed stress demand a level of metallurgical soundness available only in closed impression die forgings.

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EST. 1883

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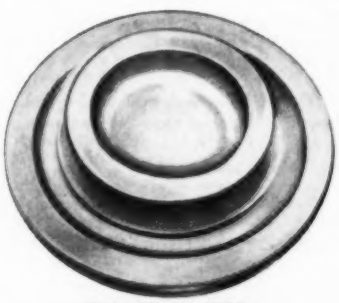
Length 22"; weight, 190 lb.; material, nickel-base, high-temperature alloy (Cutaway shows uniform wall)

Diameter, 10"; weight, 45 lb.; material, Inconel X



Diameter, 29"; weight, 1000 lb.; material, Astroloy

Length, 18"; weight, 10 lb.; material, ironbase, high temperature alloy

Length, 22"; weight, 45 lb.; material, high-strength, nickel-base alloy

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For more information write in No. 1117

GT CONTRACTS PROCUREMENTS

Some major gas turbine procurements initiated and contracts awarded during recent months by various agencies of the U. S. Government are listed. This material is from the U. S. Department of Commerce publication "Synopsis of U. S. Government Proposed Procurement, Sales and Contract Awards".

• Aeronautical Systems Div., (SKKPMG) WP-AFB, Ohio. T56-A-8 and T-56-A-10W Engines, Technical Data and Special Support Equip. (For support of the Navy P3V-1 and W2F Aircraft Programs) Contr. AF 33(657)-7026, 1 July 61—$20,741,000—Allison Div., GMC, Indianapolis, Ind.

• HQ Aeronautical Systems Div., (LMPMGC) WP-AFB, Ohio. J79-GE-11A Turbojet Aircraft Engines with Afterburner, iwa/Contractor's Specification 3-716, 21 June 60 and rev. 23 Sept. 60, and Amendment No. 1, 28 Dec. 60, (Use: Installations and Spares for F104G Aircraft) and Data. Contract AF 33(600)42761, 28 Feb. 61, 52 ea.—$9,411,000—General Electric Company, Flight Propulsion Division, Cincinnati, Ohio.

• HQ Aeronautical Systems Div., (LMPMGS) WP-AFB, Ohio. J79-GE-8 Turbojet Aircraft Engines with Afterburner and related Data. Supplemental Agreement No. 2, 14 Dec. 60, to Contract AF 33(600)41716, 16 ea.—$3,360,000—General Electric Company, Flight Propulsion Division, Cincinnati, Ohio.

• HQ Aeronautical Systems Div., (ASKPMG-1) WP-AFB, Ohio. J69-T-25 Engines, Data and Summary Bill of Materials. Letter Contract designated Supplemental Agreement No. 3, 6 Apr. 61, to Contract AF 33(600)42426, 69 ea.—$500,000—Continental Aviation and Engineering Corp., Toledo, Ohio.

• HQ Aeronautical Systems Div., (ASKPMG-1) WP-AFB, Ohio. J85-GE-5 Turbojet Engine, Contractor's Specification E-1024B, 30 June 60 and Rev. No. 1, 11 July 60, (For T-38 Aircraft) 60 ea.; J85-GE-7 Turbojet Engine, Contractor's Spec. E-1031C, 21 Dec. 59, (GAM-72 Spares) 4 ea. Supplemental Agreement No. 14, 14 Mar. 61, to Contract AF 33(600)41577—$5,266,400—General Electric Co., Small Aircraft Engine Department, West Lynn, Mass.

• Navy Purchasing Office, Washington, D. C. BuAer Model A-21-1, Turbine starter with QAD and Control Valve (Installation) 146 ea., same except (spares) less QAD and control valve, 271 ea., AD disconnect, 271 ea., Control valve, 236 ea., BuAer Model A-24 air turbine starter with QAD disconnect (installation), 25 ea., (N600(19)57259 of 30 June 61) (IFB600-902-61)—$463,560—AiResearch Mfg. Co., Div. of the Garrett Corp., Phoenix, Ariz.

• U. S. Navy Dept., Bu. Ships, Washington, D. C. Design a complete engine package including all engine accessories and 6000 RPM reduction gear, Const. engine mock-up, Mfg., rig and bench test compressor and regenerator components, Contract Nobs-84536, 30 June 61, (RFP 645-18352/.1/.2/.5)—$913,108—Spec. SHIPS-E-3720 as modified, Canadian Commercial Corp., Washington, D. C.

• U. S. Navy Dept., Bu. Ships, Washington, D. C. Gas turbine engines, including reduction gears, accessories, and control. Onboard repair parts, special tools and engineering services, 4 ea., Contract Nobs-84816, 29 June 61, (RFP 622A-11645)—$297,994—Spec. SHIPS-P-3860 as modified, Solar Aircraft Co., San Diego, Calif.

• U. S. Navy Dept., Bu. Ships, Washington, D. C. Conduct feasibility studies of main propulsion transmission systems for a 500 ton hydrofoil ship, Contract Nobs-84845, 30 June 61, (RFP 430-19775)—$45,500—Pratt & Whitney Aircraft, East Hartford, Conn.

• Dept. of the Navy, Bu. Naval Weapons, Washington, D. C. 38 GTGE 30-11 Gas Turbine Power Generator Sets and 19 GTP 30-50 Gas Turbine Power Units in accordance Spec. MIL-P-8686 (ASG). NOw 61-0993-r—$613,491—The Garrett Corp., AiResearch Mfg. Co., Phoenix, Ariz.

• HQ., San Antonio Air Materiel Area, USAF, Kelly AFB, Tex. Repair Kits applicable to T53-L-1B Qup 001. AF 41(608)-13769, 19 July 61 (SA-1-2840-E-15505 and Amend. 1), 40 to 110 ea.—$75,232—AVCO Corp., Lycoming Div., Stratford, Conn.

• HQS, Oklahoma City Air Materiel Area, Tinker AFB, Okla. Overhaul, Repair and Modification of J33-A-35 and J33-A24/24A Aircraft Engines. AF 34(601)-9533, 28 July 61 (RFP OC-2-02A-22,23 and Amend. No. 1)—$291,254—Southwest Airmotive Co., Love Field, Dallas, Tex.

(Continued on page 41)

INDUSTRY NEWS . . .

English Electric Locomotive

At the jubilee exhibition at Marylebone, England, of British Railways' locomotives and rolling stock, sponsored by the Institution of Locomotive Engineers, the 2700-hp English Electric experimental gas turbine locomotive, GT.3, will be on display to the public for the first time. This gear-driven design was built by English Electric as a private venture, and since completion early this year, has been on loan to the London Midland Region of British Railways for trial runs in the north of England and Wales.

The Pegasus Flies

The Hawker P 1127 vertical take-off strike aircraft—which is powered by the Bristol Siddeley Pegasus lift/thrust engine—has carried out successful transitions from vertical to horizontal flight at Hawker Aircraft's airfield at Dunsfold.

This follows the completion of hovering trials and a series of test flights in which the aircraft made conventional take-offs and landings.

These are the first transition flights to be achieved by this aircraft or by the Pegasus engine, and they represent an important milestone in the application of the "vectored thrust" principle to engines designed for vertical take-off.

Another Solar Unit in Industrial Application

Mid-America Pipeline Company, Tulsa, Oklahoma, has ordered a Solar Aircraft Company Saturn T-1000 gas turbine engine to be used in its propane pumping operations, it was announced by O. M. Sievert, Solar manager of turbomachinery sales.

Mid-America will use the variable speed version of the Saturn turbine coupled to a centrifugal pump to increase capacity on the west leg of the pipeline. The unit, which will be skid-mounted, will be located at the company's booster station near Whiting, Iowa, and will be used on a continuous-duty basis.

In this application, the Saturn

turbine will operate on propane fuel taken from the pipeline. It will also be capable of using any other available fuel, such as kerosene, gasoline, diesel oil or butane.

O G & E Orders 26,000 kw Unit

The Oklahoma Gas & Electric Co. will add about 235,000-kw to its Horseshoe Lake Station.

Sargent & Lundy is designing the plant which will be at least 4 per cent more efficient than a comparable steam power plant.

The combined steam-gas turbine cycle includes a 26,000-kw General Electric two-shaft gas turbine which not only supplies power for its own generator, but also supplies pre-heated combustion air to the boilers, where the exhaust heat is utilized.

Oklahoma Gas & Electric pioneered the installation of gas turbine units for electric power generation in the United States. Two 3500-kw General Electric units installed in 1949 and 1952 at OG&E's Belle Isle Station are the subject of study for engineers from all over the world, investigating new techniques in power generation.

Mr. D. S. Kennedy, Chairman of OG&E and also a past President of the Edison Electric Institute, has traveled around the world, including a recent trip to Russia, studying methods of power generation. The above is one result of his studies.

GT "COMING UP" REMINDER

NOVEMBER 9-10 Society of Automotive Engineers, Fuels and Lubricants Meeting, Shamrock Hotel, Houston, Texas.

NOVEMBER 26-DECEMBER 1 The American Society of Mechanical Engineers, Winter Annual Meeting, Statler Hilton Hotel, New York, N. Y.

DECEMBER 4-6 Institute of Aerospace Sciences, Specialists Meeting on Aerospace Support and Operations (classified sessions), Orlando, Fla.

JANUARY 8-12, 1962 Society of Automotive Engineers, Automotive Engineering Congress and Exposition, Cobo Hall, Detroit, Michigan.

JANUARY 22-24, 1962 Institute of the Aerospace Sciences 30th Annual Meeting, Hotel Astor, Times Square, New York, N. Y.

JANUARY 24-26, 1962 The American Society of Mechanical Engineers Second Symposium on Thermophysical Properties, Princeton University, Princeton, N. J.

JANUARY 28-FEBRUARY 2, 1962 American Institute of Electrical Engineers Winter General Meeting, Hotel Statler, New York, N. Y.

MARCH 4-6, 1962 American Society of Mechanical Engineers, Seventh Annual Conference Gas Turbine Power Division —Process Industries Division Conference and Products Show, Shamrock Hilton, Houston, Texas.

MARCH 12-16, 1962 Society of Automotive Engineers, Automobile Week, Combined National Automobile and Production Meetings, Sheraton-Cadillac, Detroit, Mich.

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■ Many Delavan fuel injectors are developed specially for new or unique engines: experimental gas turbine automobile engines, for example. Requirements often involve a high degree of reliability for long periods of time, as in locomotive and marine fuel injectors developed by Delavan.

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■ Delavan can bring a fund of developmental experience and specialized manufacturing ability to your fuel injection problems . . . ability that is unparalleled in the industry. Delavan is the world's largest manufacturer devoted to the design and manufacture of fuel injectors and spray nozzles.

■ *If an exacting fuel injector for gas turbines is needed . . . so is Delavan. For information write:*

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For more information write in No. 1107

AiResearch GEM's

Delivery to the Navy of what is believed to be the first completely matched fan-duct-power plant system for GEM research has been built by The Garrett Corporation's AiResearch Manufacturing Division, Phoenix, Arizona. In the Navy's David Taylor Model Basin, near Washington, D. C., it will serve to provide complete design parameters for air handling systems associated with future operational ground effect machine (GEM) vehicles.

Announcement of the Navy contract marks the first disclosure of a broad GEM program conducted at Garrett's Phoenix plant over the past two years. Current work includes study of systems for GEMs to 100-ft. in diameter. Powered by a 150-shp AiResearch small gas turbine engine, the unit's 33-in. fan supplies over 60,000-cfm of air through a matched diffuser and 90° bend. Overall engine-fan-duct system efficiency is better than 81%.

Allison Prop-jet Convairs Exceeding Performance Guarantees

Twin-engine Convair transports converted to Allison prop-jet power are exceeding performance guarantees by a wide margin, according to domestic corporate operators who have a total of 13 of the modernized aircraft. Approximately 16,000 engine flight hours without a premature engine removal already have been compiled by the Allison prop-jet Convairs.

Two of the converted transports, owned by Union Oil Company of California, not only are outperforming the original piston-powered versions, but are doing it at lower fuel cost (22.6 cents a mile, as compared with 33.7 cents a mile in the piston engine configuration). Other operators also are reporting reduced maintenance and cost-per-mile expenditures. FAA-certified figures show that CAR landings at sea level under standard day conditions have been demonstrated in 4160-ft. instead of the guaranteed 4400-ft. Actual cruise air speed is in excess of 350-mph.

Newest operator to announce purchase of the conversion package is the Federal Aviation Agency, which later this year will place in service five Allison-powered Convair 440s. These aircraft will be used to monitor the nation's intermediate attitude navigational systems to assure proper direction and frequency of radio transmissions.

TBO Extended on CJ-805-3

Both Trans World Airlines and Northeast Airlines have been granted approval from the Federal Aviation Agency to increase the Time Between Overhaul for their CJ-805-3 turbojet engines to 1000-hrs.

These General Electric powerplants have only been in service on the Convair 880's of these two airlines for about four months. "From an industry standpoint, this rate of

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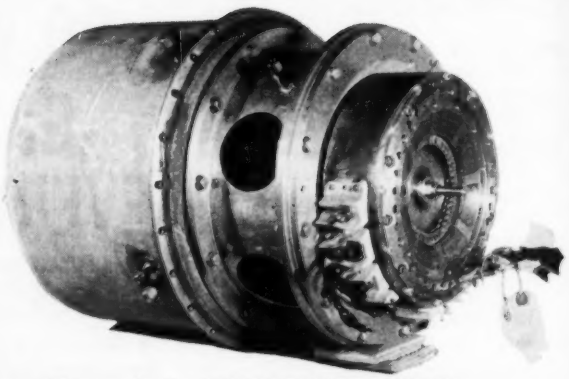

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advance in allowable time between overhaul is extremely rapid," according to T. J. Harris, Manager of Maintenance and Operations Engineering for G. E.'s Commercial Engine Operation.

Mars Powered Checked System

Solar Aircraft Company has received an order for gas turbine-powered generator sets for a new electronic pre-flight checkout system developed by Republic Aviation Corporation, announced O. M. Sievert, Solar manager of turbomachinery sales.

The electronic system, dubbed RADFAC (Radiating Facility for Aircraft Flight Line Testing), permits Air Force fighter pilots to give their planes a complete electronic checkout in 90 seconds without moving from the cockpit.

Sikorsky-Sud Helicopter

Sikorsky Aircraft, a division of United Aircraft Corporation, and Sud Aviation, of La Courneuve, France, have signed a technical cooperation contract under which Sikorsky will provide design, test and construction assistance for Sud's new Super Frelon 3210 helicopter. The Super Frelon has been proposed by Sud for military operations. The company has already been granted a contract by the French government for the construction of two protoypes. The helicopter will have a gross weight of 24,250 pounds and will be powered by three Turbomeca engines of 1,300-hp each.

Charles M. Echeverria of Sikorsky's engineering department is in charge of the technical assistance program as project engineer. Assistant project engineers will be Frederic C. DeSibert, who will be stationed in France, and Joseph J. Koch, at Sikorsky. Other engineering assistance will be drawn from the Sikorsky organization when necessary.

Time Between Overhauls

The Federal Aviation Agency has granted Delta Air Lines a 1200-hour Time Between Overhaul for the General Electric CJ-805-3 turbojet engines that power Delta's fleet of Convair 880's. Effective April 17, 1961, the authorization also includes a TBO of 1500-hours for engine accessories and controls.

Hiller Helicopter Powered by the PT6B

Under study by a number of airframe manufacturers for over a year, Canadian Pratt & Whitney Aircraft's versatile PT6 free turbine engine has one of its first prototype airframe applications in Hiller Aircraft's new helicopter, Model 1099, which has been flying for several months. Developed for both civilian and military markets Hiller's six-place Model 1099 has aft clam-shell doors for easy access of passengers and cargo. The aircraft is powered by a single prototype PT6B.

(*More Industry News page 42*)

FRANKLIN 6VS-335 TURBOSUPERCHARGER ENGINE

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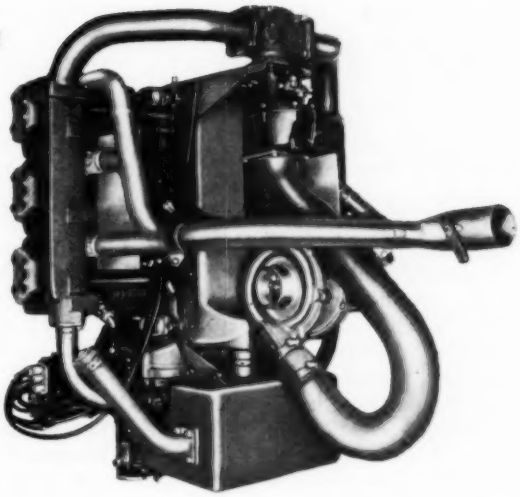
Franklin 6VS-335 Turbosupercharged Engine for Helicopters (FAA Type Certificate No. LE2)
Horsepower 240 at 15,000 ft.
Weight, lbs. 360

(Turbocharged model for fixed-wing aircraft is in process of certification.)



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GT PEOPLE PLANTS PLACES

Fowden Heads Code 645

CDR Wilbur M. M. Fowden, Jr., U. S. Navy, is now Branch Head of Code 645, Internal Combustion and Gas Turbine Branch, Bureau of Ships, Department of the Navy, Washington, D. C.

He was born in Oakland, California July 14, 1920. Attended public schools in that city and received B.S. in M.E. from the Polytechnic College of Engineering in 1942. Received Commission in U. S. Naval Reserve immediately after graduation and served in destroyers in the Pacific Fleet during World War II. Upon cessation of hostilities attended U. S. Naval Postgraduate School, Annapolis, Maryland and Rensselaer Polytechnic Institute where Master of M.E. degree was awarded in 1948. Has previously served in the Gas Turbine Branch from 1952-1956.

Member of ASME; Soc. of Nav. Arch. & Mar. Engrs; Am. Soc. of Naval Engineers; U. S. Naval Institute; and North East Coast Institution of Engineers and Shipbuilders. Co-author or author of several papers for ASME, SNAME and Am. Soc. of Naval Engineers. Received Gas Turbine Power Division, ASME special award in 1956 at first Gas Turbine Power Division Conference.

Promotions at Hamilton Standard

Donald C. Zipfel has been appointed sales manager of the overhaul and repair department at **Hamilton Standard.**

The promotion of **Donald Ramaker** to chief of design of the engineering department at Hamilton Standard, division of United Aircraft Corporation, has also been announced.

Manager Research

Martin A. Mayers is now manager of research for the **American Society of Heating, Refrigeration and Air Conditioning Engineers,** located at headquarters in New York City. Martin Mayers will fill this position admirably. The old timers in the gas turbine business well remember him, as he was then one of them. Like many others formally in the gas turbine business, he has broadened out his interests to include other phases of engineering.

Ralph W. Walker Named Sales Engineer

Appointment of **Ralph W. Walker** as Sales Engineer for **WaiMet Alloys Company,** division of Howe Sound Company, Dearborn, Mich-

igan, has been announced by Royer F. Waindle, President. In his new position Mr. Walker will handle sales and provide technical assistance on standard and special alloys for investment casting.

Bristol Siddeley Appointment

Alexander Johnston has been appointed Public Relations Manager to **Bristol Siddeley Engines Limited.** He will assume overall responsibility for press relations, advertising, exhibitions, films and the Bristol Siddeley Journal.

Selwyn Sharp, Public Relations Officer of the Power Division, will devote his whole time to the expanding activities of this side of the Company's work.

R. H. Butcher continues as Press Officer of the Aero Engine Division at Bristol.

Levine GE Manager of Marketing

S. J. Levine has been appointed Manager of Marketing for the Marine and Industrial Operation organized recently at the **General Electric Company's** Flight Propulsion Division headquarters at Evendale. He will be responsible for developing the marine and industrial market for G. E.'s turboshaft engines which include the 20,000-horsepower Model 240, and the 1000-horsepower Model 720.

Clark Bros. Appointments

Clark Bros. Co., Division of Dresser Industries, Inc., announces the appointment of the following men as sales engineers on Clark engines, compressors and gas turbines:

M. S. "Mel" Kenady, Amarillo office, formerly in sales engineering in the gas-petroleum industries since 1945.

Z. B. "Zobo" Deer, Tulsa office–transferred from Amarillo after two years in sales engineering there. Mr. Deer was previously in supervisory work with Celanese Corporation of America.

Edward S. Leonard, Houston office, formerly in application engineering, sales engineering and marketing work at Clark headquarters in Olean, N. Y. for more than ten years.

Thomas R. Bett, Shreveport, following four years as application engineer in that office and previous work in the Clark marketing section of Olean.

Boeing Changes

D. J. Euler, vice president **Boeing Industrial Products Division** has announced that **S. D. Hage** has been elevated to technical assistant reporting direct to him. Dan Hage, one of the pioneers in the development of the small gas turbine engine, will concentrate on new product plans. **Vincent Moore** will be the division's new chief engineer. He came directly from Hamilton Standard Division and prior to that was with Curtiss Wright for 20 years in the design and development of aircraft engines.

W. B. Anderson, associated with the Boeing turbine program since its inception in the mid-1940s, is now assistant chief engineer and will have direct supervision of engineering activities concerned with development and production of Boeing gas turbine engines.

GT HOT LINE

JET PROPELLED GROUND VEHICLES AREN'T EVEN NOTICED

Did you ever stop and think of the thousands of miles people ride each year in jet propelled ground vehicles. For example when your jet lands at Idlewild it takes about 7 minutes traveling, at least a mile, over the road from landing strip to terminal . . . A jet propelled auto would be a curiosity but the jet propelled plane taxiing about on air field is hardly noticed . . . So, take all the landings and take offs multiplied by 1 mile and we find jet vehicles travel 1000's of miles each year on the ground.

GENERAL ELECTRIC ENGINES RACK UP MORE RECORDS

The 3-kilometer speed record of 902-mph set recently by the Navy's McDonnell F4H Phantom II boosted to 19 the number of world class records set by aircraft powered by the J79 turbojet engine. This is more than one-third of all world jet-class records . . . Perhaps even more significant is the fact that of the 56 class records recognized by the international aviation agency, Federation Aeronautique Internationale, only nine are at speeds greater than 1000 miles per hour and the General Electric-built J79 has powered U. S. aircraft to eight of them. The other record is also held by a U. S. jet, powered by Pratt & Whitney's J75.

CENTRAX 600-HP UNIT READY FOR LIMITED PRODUCTION

This single-shaft British turbine will be in semiproduction early in 1962. It is expected to sell at a reasonable price based on its limited production. Later in 1962 the unit will be equipped with a stationary heat exchanger to improve its efficiency where the application warrants it.

NAVY EVALUATION OF GAS TURBINES IS FAVORABLE

In a BuShips Journal article by C. S. Farmer, Jr., the following is reported. "The contract recently awarded by the Bureau of Ships is for 125 shp gas turbine inboard-outboards. These . . . will be installed and evaluated in a Navy personnel boat . . . With the present trend towards use of high speed and hydrofoil craft, units of 125 hp and greater appear to have an unlimited potential in the Navy as well as the commercial market."

SIKORSKY S-62 SHOWS HIGH DEGREE OF DEPENDABILITY

Mr. C. M. Belinn, president of Los Angeles Airways said after one year of S-62 service he couldn't recall "being exposed to a more dependable and trouble-free machine in my 35 years of operating aircraft of all types." The S-62 has a GE-T58 turbine.

1962 AUTOMOTIVE ENGINES WILL INCLUDE GAS TURBINES

Right now it looks like 1962 will be the year gas turbines for automotive use will come forth. It now looks like at least 4 will be on the market, both here and overseas, and that turbines will have regenerators. This means the turbines should have a better efficiency than the gasoline engines they replace. These engines will first be used in heavy duty equipment before actually being placed in an auto. In 1963 we hope to see the regenerative turbine appear in the auto.

Aircraft Engines of the World 1961/62 is just out — get your copy from Paul H. Wilkinson, 734 15th Street, N.W., Washington 5, D. C.

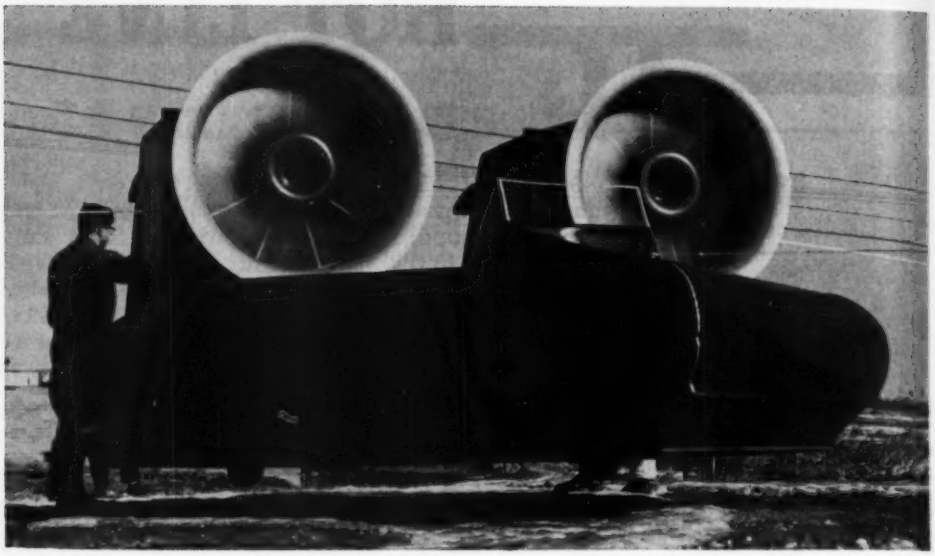


Figure 1—Gem III ground effect machine is designed as an experimental prototype vehicle, uses a peripherally-exhausted sheet of air as support cushion.

Gas Turbines Powers GEM

Two Solar YT-62-2 engines are powering GEM III, a ground effect machine now undergoing tests.

Two Solar YT-62-2 engines, powering the GEM III (Ground Effect Machine), represent the first actual application of gas turbines to the new and rapidly developing area of air cushion vehicles. This vehicle, designed as a cooperative venture between the Office of Naval Research, the U. S. Navy David Taylor Model Basin and National Research Associates, Inc., was constructed by National Research Associates, Inc., under Marine Corps Contract. It passed acceptance tests and was delivered in January 1961. It is now undergoing a series of demonstrations and tests at the U. S. Navy's David Taylor Model Basin, largely concerned with performance and stability and control aspects.

GEM III, Figure 1, designed as an experimental prototype vehicle, is an outgrowth of such programs as the Navy's "Skimmer" model test program, various Office of Naval Research studies, and research and development activities carried out over a period of several years by National Research Associates, Inc. They are a pioneering organization in the field of air cushion vehicles. These latter research and development activities included a comprehensive feasibility study and model test program performed by National Research Associates, Inc., under contract with the Army Ordnance Tank Automotive Command. These tests contributed to the development of the Army's Free Air Suspension System vehicle and the Marine Corps' GEM I, operated by the military services in this country.

GEM III uses a peripherally-exhausted sheet of air to generate supporting air-cushion pressure under the vehicle. The peripheral air-sheet is exhausted downward and inward at a 45 degree angle from vertical, and the equilibrium established between the change in momentum of the air sheet as it leaves the vehicle and the lifting pressure within the jet sheet governs the magnitude of the supporting base pressure.

The air necessary to supply the peripheral jet sheet or curtain is supplied by two 38-in. diameter, forward-facing, adjustable-pitch, axial-flow fans, each of which is driven through a timing-belt-drive reduction system. Air from each fan passes through a diffuser nacelle into a common plenum which feeds the peripheral jet slot. Slots, 4-in. wide, located in the vehicle base, provide stabilizing jet-sheets, which divide the base into isolated, fore-and-aft, and lateral pressure pad-areas. These pads generate pitch-and-roll restoring moments, when the vehicle is displaced from the equilibrium position. Operator-controlled "spoilers" in the fore-and-aft and lateral elements of the peripheral jet are included, as a means of further augumenting vehicle pitch-and-roll stability.

Presently incorporating what is known as a fully integrated lift-and-propulsion system, fore and aft motion is produced by forward or rearward deflection of the peripheral jet air sheet. This is accomplished by a system of flexible vanes in the peripheral jet slot, which are controlled by the operator.

Differential deflection of these vanes on each side of the vehicle produces required turning moments for steering. This type of propulsion method is effective in

generating limited forward speeds without excessive loss in vehicle operating height. For higher speeds, a separate propulsion system is being contemplated.

GEM III, hexagonally shaped in planform, measures slightly less than 23-ft in length and is 12-ft in overall width. With a design gross weight approaching a ton, a hover height of 12 to 15-in. is achieved. Forward speeds are currently limited to 25 to 30-mph with the present integrated propulsion system. At the design operating condition total fan air flow is of the order of 100,000-cfm at a total pressure rise of 6 inches of water.

The basic structure of the GEM III is aircraft-type riveted aluminum alloy. Foamed plastic provides flotation in the vehicle base to allow operation in water. Zippered inflatable sides are incorporated on the plenum base to reduce weight and to provide a flexible bumper as well as to allow ready access to the vehicle interior.

Power Plant

Two Solar YT-62-S-2 gas turbine engines, see Figures 2 and 3, are used for powering the craft. Modifications were also incorporated in the control system, and a centrifugal clutch was installed in the drive system to permit limited variable speed operation.

Modifications were made to the turbines to allow horizontal installation. These include extension of the oil-scavenging inlet passage to the lowest point in the reduction gear housing, and installation of metal shields around the lower gears to prevent excessive oil pickup.

Control system changes consisted of installation of a new cam in the fuel control to extend the speed range of the fuel burst feature during acceleration. In addition, the acceleration fuel schedule is extended to provide more power margin for accelerating the fans, and provisions are incorporated for an additional throttle detent at the clutch engagement speed. This provides a power modulation range between clutch engagement speed and rated engine speed.

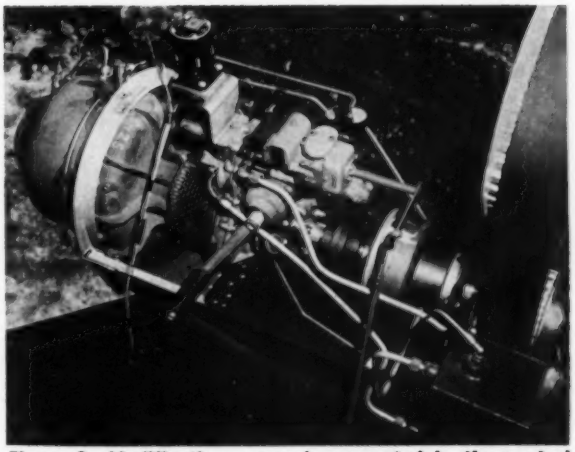


Figure 2—Modifications were incorporated in the control system, and a centrifugal clutch in the drive system permits limited variable-speed operation. Engine is rated 70-shp @ 80°F.

Design of the centrifugal clutch is such that the fans are fully engaged at about 87% rated speed. The engine is rated at 70-shp at 80°F, at an output shaft speed of 4045-rpm. Fuel consumption at rated power is 71.5 pounds per hour. Engine instrumentation in the GEM III includes exhaust temperature indicators, engine percent speed indicators and oil pressure gages. The helicopter installation warning devices indicating limiting exhaust gas temperature and engine output power are not used in the GEM III installation.

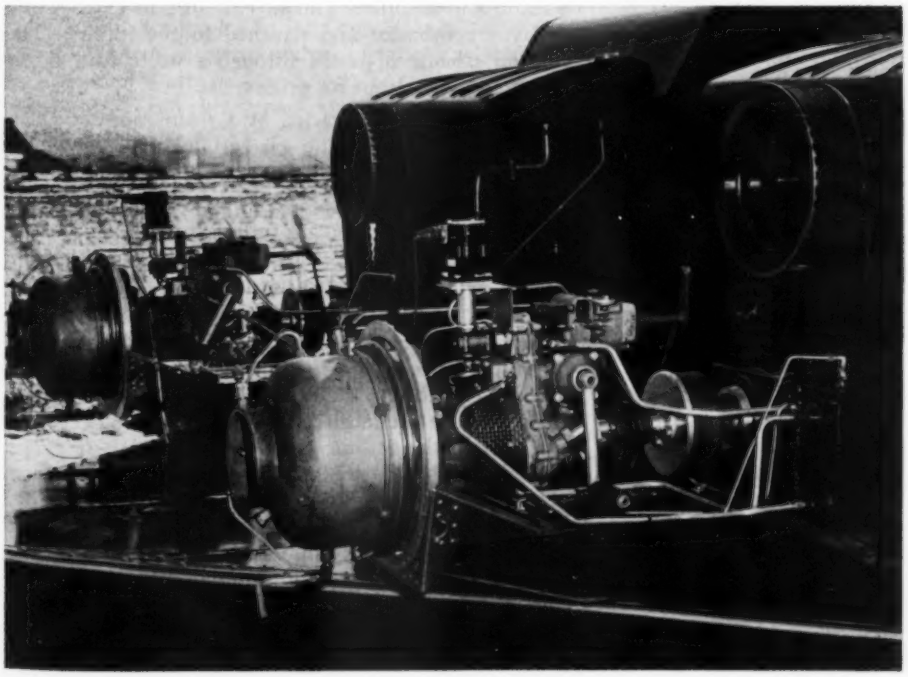


Figure 3—Two Solar YT-62-S-2 gas turbine engines power the craft. Each develops 70-shp at 80° F; fans are fully engaged at 87% speed.

Gas Turbines for Process Industry

by C. E. Knight
Small Steam and Gas Turbine Engineering
Westinghouse Electric Corporation

Standard model gas turbines provide economic advantages and have flexibility for application in a broad range of services.

The economics of applying the gas turbine in the process industry is being proven throughout this country. By describing units in operation we point out the flexibility of using standard models to achieve this economic advantage.

The gas turbine was selected because it was best suited for a particular process requirement. It was selected for supplying compressed air, hot gases, mechanical power or combinations of these requirements. Of the gas turbines sold by Westinghouse Electric Corporation, 19% have been applied as part of a process system; this does not include gas turbines used to mechanically drive process compressors or pumps. The process requirements have been met by the application of the gas turbine best suited and have ranged from 1800-hp to 15,000-hp.

The selected applications are grouped and discussed in the following categories:

1. Integrated Pressurized Process
2. Gasifier
3. Extraction
4. Mechanical Drives
   a. Gas-Steam Turbine Combination
   b. Throttled Compressor Inlet

Integrated Pressurized Process

An 1800-hp gas turbine is being applied for the production of nitric acid. The gas turbine compressor discharge is utilized for supplying compressed air to the process.

For this application, the compressor takes suction from the atmosphere and delivers the air through a cooler and booster compressor at 120-psia and 450°F to a nitric acid absorber. The air is heated to 1250°F in a catalytic combustor and returned to the turbine. The turbine exhaust is passed through a waste heat boiler which supplies steam for process use.

The gas turbine is started by a steam turbine which is disconnected when the gas turbine and process are self-sustaining.

The air flow to the process can be varied approximately 30% by changing the gas turbine speed. Any fuel requirements of the gas turbine for maintaining a process balance can be supplied either before or after the process.

Factors for consideration when selecting an integrated pressurized process are the chemical analysis and solid particles carried into the turbine by the process exhaust. Assuming the chemical carryover from the process will not damage the turbine a dust load up to 0.01 grains per cubic foot and 95% of the particles being less than 20 microns in size will not seriously reduce turbine life. Particles over 100 microns are not permitted. The work balance between the compressor and turbine is largely dependent on the pressure loss in the process and can be compensated as required. The maximum permissible process outlet gas temperature is fixed by the metallurgical limits of the turbine components.

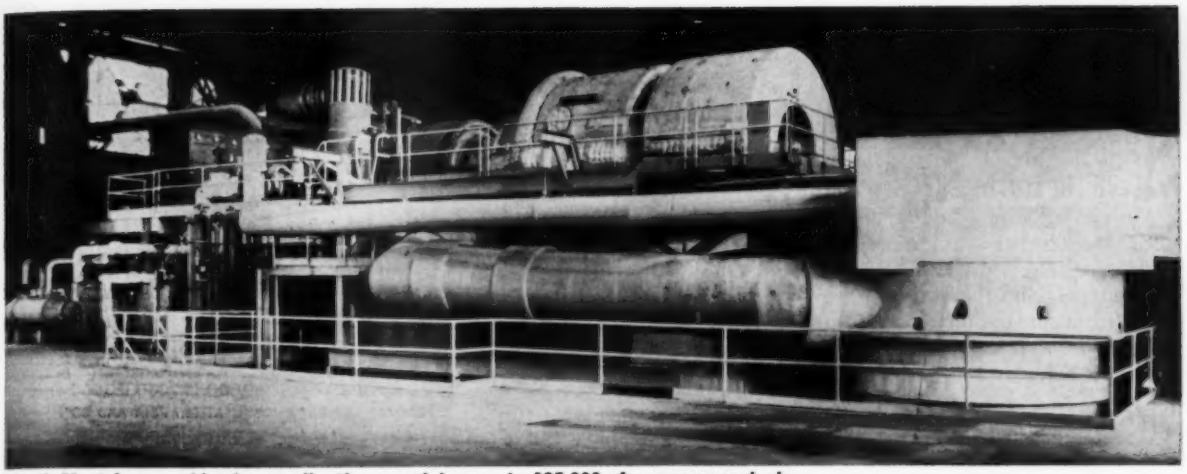


Fig. 1 Blast furnace blowing application supplying up to 125,000-cfm compressed air.

Gasifier

A butadiene process makes use of two Westinghouse Model W-81 gas turbine exhaust gases. The gas turbines are utilized in this application to supply pressurized high temperature turbine exhaust gas containing a combustible quantity of oxygen from the compressor inlet air.

The method of combining the exhaust gas of two turbines to provide the required air flow for the process is shown in Figure 2.

Each compressor takes suction from the atmosphere and delivers the pressurized hot gas through a common header to a catalyst bed at approximately 1100°F with the turbine back pressure being established by the process. The turbine back pressure is dependent on the resistance of the bed, associated piping and heat-recovery apparatus. For this system the turbine exhaust was 1000°F and 28.2-psia for an inlet condition of 80°F and 14.7-psia. The higher temperature of 1100°F is obtained by the use of a process combustor. The air flow to the catalyst bed can be varied approximately 30% by changing the gas turbine speed for a gas flow of 120 lb/sec at rated speed.

The energy requirements of the gas delivered to the process remains constant and can be burned in the gas turbine combustor or the process combustor before entering the process. Sufficient fuel is supplied to the gas turbine combustor for the turbine work to equal the work absorbed by the compressor plus any leakage or radiation losses. In this application no external load or additional power is applied during operation; however, if requirements were such, the gas turbine could be readily adapted.

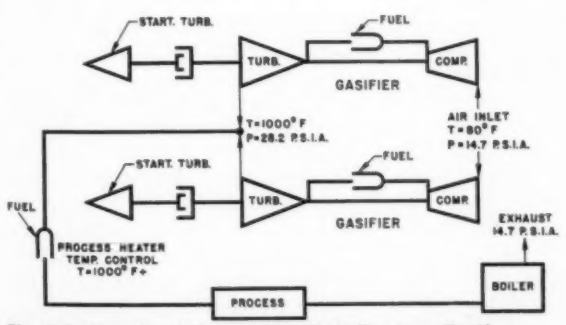


Fig. 2 Schematic of twin-turbine butadiene application.

Each gas turbine is started by a steam turbine which is disconnected when the gas turbine is self-sustaining. When selecting a gas turbine for a gasifier, the following factors should be considered. The temperature at the process inlet can be maintained by increasing the fuel rate at the turbine combustor or the process combustor. The pressure at the process inlet can be established by varying the process system back pressure and will be limited by the mechanical and temperature limits of the turbine and process system.

Extraction Units

Applications requiring large amounts of compressed air at pressures from one to three atmospheres, of which the process outlet gas would not be suitable for return to the turbine, would be in the extraction category.

This differs from the gasifier application by extracting compressed air of the axial flow compressor before it enters the turbine combustion chamber. At rated conditions, 38% of the air flow is available to the process and the remaining 72% passes to the turbine combustor. After firing in the combustor the gas passes through the turbine. As in the gasifier application no external load is applied for the systems in operation. Figure 3 shows the wide operating range which is obtainable for a gas turbine designed for a given application. The flexibility of this machine is emphasized by the feature of varying the air flow to the process from 0 to 100% and at any pressure below a performance speed parameter. The machine as shown in Figure 1, supplies up to 125,000-cfm for blast-furnace blowing.

The gas turbine is started by a steam turbine and assisted to approximately 60% design speed. The unit is self-sustaining once started and uses blast furnace gas as a primary fuel with distillate oil as emergency standby fuel.

The gas turbine selected for this application would be

dependent on the air flow and pressure requirements of the process within the mechanical and temperature limitations of the unit. By balancing the air flow between the requirements of the process and the flow to the combustion chamber an external load could be driven.

Mechanical Drives

Mechanical drives in this article are gas turbine applications selected as the most suitable prime mover to drive compressors or pumps in a process system.

The two applications selected for this portion are different from conventional drives. Most mechanical drives utilize the high temperature turbine exhaust gas by passing it through a waste heat boiler.

Gas-Steam Turbine Combination

A gas turbine and steam turbine are tandem connected as a direct drive for a centrifugal compressor in a refrigeration system.

When small percentages of additional power is required above the temperature or mechanical limitations of a standard frame size gas turbine, a booster turbine is utilized. By direct connecting the starting turbine and/or booster turbine to the gas turbine shaft, 15% additional power was made available for this application.

This gas turbine is a standard Model W101 in the line offered by Westinghouse Electric Corp. Under certain operating conditions the process horsepower requirements exceed the gas turbine rating. To satisfy this condition, the starting turbine horsepower rating was increased above starting requirements and was direct connected for continuous operation.

Control for increasing power output of the booster turbine is provided as the gas turbine reaches the temperature limitation imposed without reducing the speed of the driven centrifugal compressor. If the gas turbine overtemperature still exists after the booster turbine output is maximum, the process signal is overridden and the speed reduced.

The compressor takes suction from the atmosphere and delivers it to the combustion chamber. Fuel is admitted through six fuel nozzles and combustor baskets to the turbine. The exhaust gas passes through a waste heat boiler and then to the atmosphere.

As noted above, the starting turbine requirements were increased to 1950-hp at 6000-rpm to meet the process requirements and act as a booster turbine. The booster steam turbine uses process steam with the following steam conditions: 590-psig, 740°F with an exhaust pressure of 275-psig.

This type of application is favorable when process steam is available for a booster turbine and additional torque is required to drive the load above that available from a selected gas turbine. As external power is required for starting the gas turbine, this equipment may be utilized economically for peak operation. Since the booster turbine is directly connected, a minimum steam flow is required for cooling purposes. The maximum horsepower output is limited by the metallurgical limit of the turbine as well as the available steam or gas for the booster turbine.

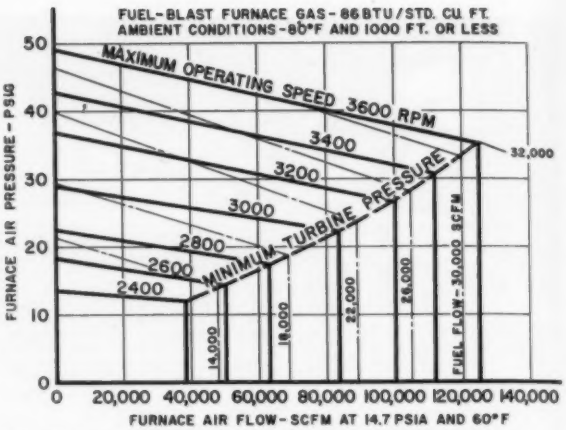


Fig. 3 Pressure-flow data for blast furnace blower illustrated in Fig. 1 on previous page.

Throttled Compressor Inlet

After an economic study of drives suitable for driving a centrifugal compressor in a hydrocarbon extraction plant, a standard Westinghouse Model 101 gas turbine was selected with a booster turbine. By utilizing the exhaust gas in a waste heat boiler this approach was the most advantageous.

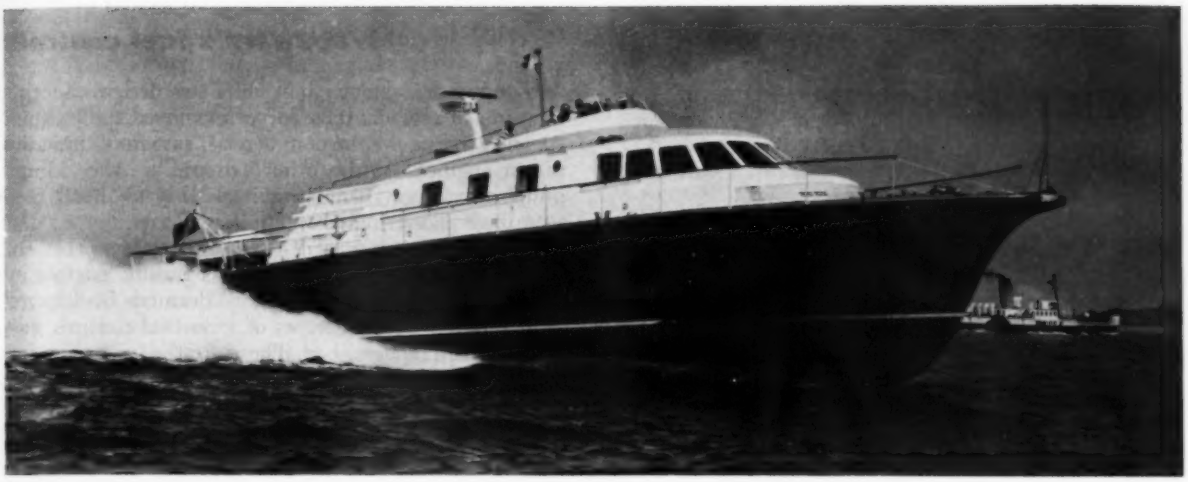
The unusual feature of this application was selecting the equipment to supply the required horsepower at rated ambient (80°F) inlet conditions and maintain the turbine exhaust gas temperature by varying the flow at lower ambient inlet conditions with emphasis placed on the thermal efficiency of the system.

This was accomplished by increasing the required starting turbine rating and direct connecting it as a booster turbine. To control the gas turbine temperature a throttling damper was added at the turbine compressor inlet. The throttling damper location may be seen in Figure 4. By placing the damper in the inlet ducting of a standard model gas turbine an economic advantage was obtained over that of redesigning to incorporate a variable compressor inlet guide vane. Due to the gas turbine operating field flexibility the process requirement was met without changing the blade path of the machine.

When operating on "Process Control" the operator selected the required turbine exhaust temperature for operation and it was automatically maintained except in the event the metallurgical limits of the turbine were exceeded. If an overtemperature occurs the Process Control is overridden to prevent damage to the turbine.

Conclusion

The gas turbine has shown the flexibility with which it can be adapted within the past 5 to 6 years by the varied applications in the process industry. This acceptance is based on economic considerations for each installation and equipment reliability. With regard to the wide selection of available standard models, the flexibility of adapting them to a particular process, lower installed costs, and lower over-all operating costs, the gas turbine is being selected instead of other prime movers.



Three Gas Turbines Power 50-knot Yacht

Private yacht based on "Brave" class fast patrol boat design is fitted with three Proteus engines producing 10,000 shp.

"Mercury" is a private yacht believed to be the fastest private yacht in the world. It has a combined propulsion power plant of about 10,000-shp, producing a top-speed in excess of 50 knots.

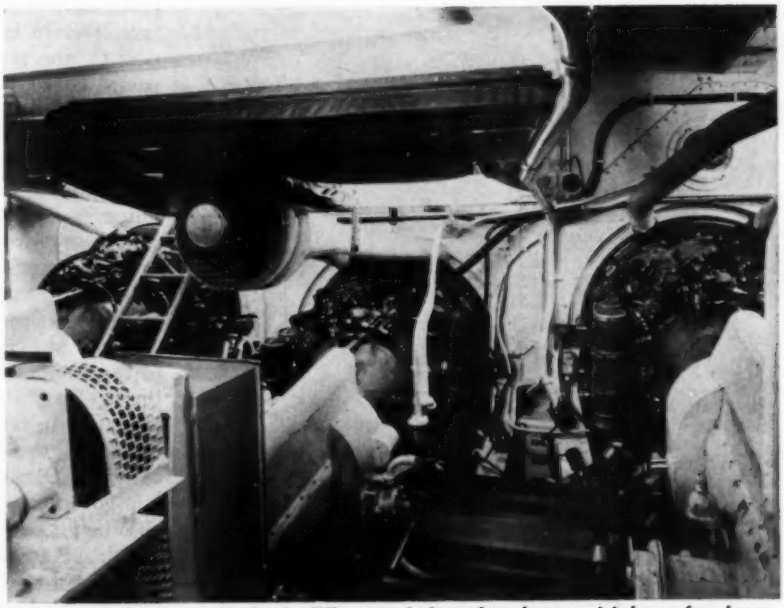
Designed and built by Vosper Limited for Mr. Stavros Niarchos, the craft is now in service. The design is based on the "Brave" class Fast Patrol Boats built by the same company for the Royal Navy from a Vosper/Admiralty design. Like them, the yacht is powered by three Bristol Siddeley Marine Proteus gas turbines.

The Marine Proteus is a sea-going version of the Proteus turboprop engine used in the Bristol Britannia airliner. It embodies a free power turbine and is, in consequence, so flexible that it can be used satisfactorily for all slow speed operations. Neither "Mercury" nor the "Brave" class Fast Patrol Boats have any auxiliary propulsion machinery. The use of a free power turbine enables the engine to deliver extremely high power at low or medium propeller speeds, which gives the vessel rapid acceleration.

Engines of this type have many advantages for this type of application. Their weight is about a quarter of that of a diesel of equal power or, to put it another way, they deliver four-times the power from equal weight if evaluated on this basis. And they are correspondingly compact.

The absence of reciprocating movement means that there is virtually no vibration. The Britannia

(*Continued on page 32*)



Maintenance is extremely simple. When needed, engine changeout takes a few hours.

FOLLOWUP REPORT:

More Gas Turbine Controls

Broadening the spectrum of gas turbine engine control systems currently in use and available.

CREDITS: First three articles are abstracts from the following papers presented at the SAE Heavy-Duty Vehicle Meeting & Display, Milwaukee, Wis., September 11-14, 1961 and planned by the Powerplant Activity. Papers are listed in order of article presentation.
SAE Paper 398E titled "The Design and Development of Two New Industrial-Type Fuel Controls" by F. W. Newburgh and Bruce Ingold, Woodward Governor Company.
SAE Paper 398B titled "A Literal Acceleration Limiting Fuel Control for Gas Turbine Engines" by A. N. Carras, AiResearch Manufacturing Div., The Garrett Corp.
SAE Paper 398D titled "The Trend in Fuel Control Systems for Small Gas Turbines in England" by J. S. Clarke, Joseph Lucas, Ltd., C. K. J. Price, Lucas Industrial Equipment Ltd., and C. H. Bottoms, Lucas-Rotax Ltd.
Data for the final article was obtained from de Havilland.

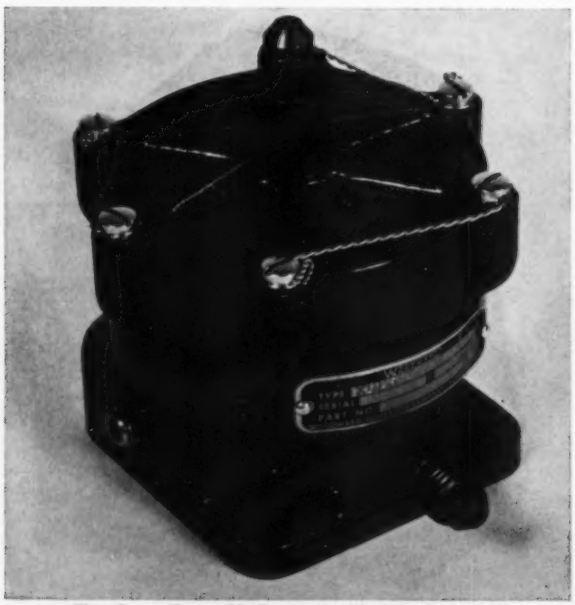


Fig. 1 — Type 1945 gas turbine fuel control

Woodward's fuel controls

Woodward is involved in different design concepts to produce fuel controls for primemover applications. At one extreme are the commercial "cast iron" units for piston engines. At the other extreme are the "aluminum" aircraft gas turbine controls that to diesel men seem built like extremely complicated toys.

When it became evident that a very large market was to be realized for the industrial gas turbine engine, redesign of existing controls was deemed inadequate. Work started on three types of industrial controls, two of which will be described. These are the type 1945 and type 1910.

Our type 1945 is for engines of 50 to 600 horsepower. Its basic design goal was low initial cost, with life and weight as secondary objectives. As it turned out, the concept was simple enough that light weight resulted without much effort. This same simplicity provides a unit with relatively long life, especially in clean fuel.

Our type 1910 is for engines of 1000 to 20,000 horsepower. Its basic design goal was long life so the control is highly biased by diesel governor practice. Early in design we realized that it would also be well-suited to aircraft applications so we have made sure that the control is also compatible with flight requirements.

Type 1945 Design

Fig. 1 shows the type 1945, a simple control for low-compression, low-altitude gas turbines. It is about 3-in. high, about 3-in. in diameter, and is designed for mounting either on top of a pump or independently. It will produce an acceleration fuel flow as shown by Fig. 2 and will control steady-state fuel. It contains five moving parts as shown in the schematic. (Fig. 3)

Fuel enters through port A. Bypass valve B maintains an essentially constant pressure drop from inlet port A to outlet port C, the discharge to the engine nozzle. A relief valve protects the fuel pump from excessive pressure. Should we add restrictions between port A and port C, the bypass valve will open, more fuel be bypassed back to the pump, and less will be sent on to the engine.

As you may have suspected, we do add restrictions. One is at orifice D and it is varied in size by needle, E, that is moved by governor weight F. As governor weight F moves out, needle E partially restricts flow through D, pressure drop increases, and bypass valve B, returns more fuel to the pump.

Another restriction is in series with D at G. This hole is varied in size by speed weight H working against leaf-spring I. At low engine speed, the needle J restricts flow to the engine to starting-fuel levels. As speed increases, the needle gradually moves out of orifice G, permitting more fuel to flow to the engine. When requested speed is reached, speed governor weight F moves needle E into orifice D, further reducing engine fuel flow to maintain governed speed.

When small load changes tend to change engine speed, the governor weight will move needle E in and out of the orifice to permit a little more or a little less fuel to flow to the engine combustion chamber. Should

a large decrease in load occur, the governor weight will sense the resultant increase in engine speed and will close the orifice until the fuel energy supplied just matches the energy needed to maintain the engine on speed at the new load.

Type 1945 Design Considerations

To provide spring I with sufficient spring load for the centrifugal force of weight H to work against over the wide speed range, a relatively simple cam device as shown at K was employed. This avoided resort to the usual valve-servo-feedback arrangement or parabolic spring design. With this cam, the effective spring scale is changed as a function of flyweight position. Position of needle J, therefore, can be made linear with speed. Fuel flow to accelerate the engine is preset by selecting the proper contour of needle J.

Maximum horsepower limiting is accomplished by screw adjustment which limits travel of flyweight H and thereby flow. Minimum flow is set by positioning needle J with flyweight H against its low-speed stop.

To allow accurate positioning of the needles in their respective orifices, flyweights are suspended horizontally on cone points to reduce friction. This feature also eliminates bearing costs without sacrifice of accuracy.

Although it would be desirable to have variable speed setting of the governor section on some applications, it was not considered here because of the cost penalty it would impose on the users of a fixed, single-speed unit. Variable speed setting will be added as necessary.

Type 1945 Status

At this time, prototype controls have successfully passed component and preliminary engine test stages. Life testing of one unit is in process while others are gaining time at the engine builder's facilities.

Results thus far are most gratifying and we anticipate no problems involving major redesign. However, we do expect the normal troubles associated with any new design and will incorporate changes dictated by these experiences.

Type 1910 Design Considerations

You may know that the military has recently specified that their engines and accessories be able to run in a mixture of Arizona road dust, sharp silica sand, jewelers rouge, naphthenic acid, cotton line, and salt water all stirred up with a little fuel. This requirement, plus tests some of our customers have run, purposely or by mistake, required that the fuel control must eat plastic caps, lockwire, rusty water, and in at least one case, a detergent. This made us suspect the wisdom of submerging precision components of our computing-type controls in this stuff.

An obvious solution is to supply the computing components with clean lubrication oil. This is exactly what we do in our type 1910, a unit designed for high compression-ratio engines.

The type 1910 concept is of a self-contained oil-lubricated computer section with an output shaft that could be used to position either a liquid or gaseous fuel metering valve. We intended that the computer package be designed for use with adapters for mounting the control to various engines and that the adapters could contain special equipment for use on specific engines. The computer package is shown in Fig. 4.

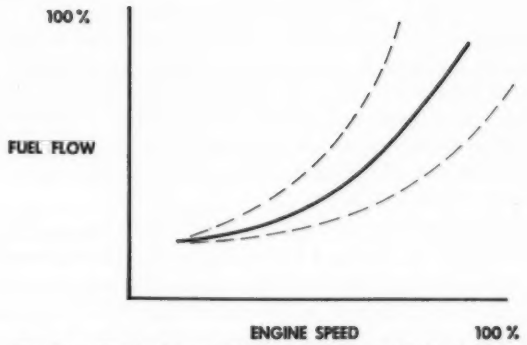


Fig. 2 — Typical type 1945 acceleration fuel schedule

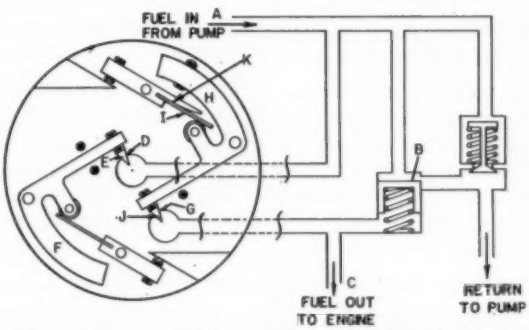


Fig. 3 — Schematic of type 1945 gas turbine fuel control

The 1910 has an all-speed governor which is limited

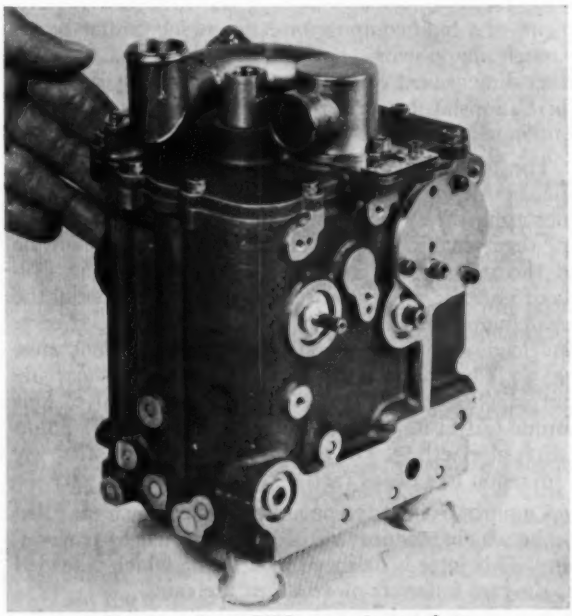


Fig. 4 — Type 1910 computer package

by a lever positioned by cdp (compressor discharge pressure), rpm, and cit (compressor inlet temperature). Output of the combination moves a fuel valve to regulate the amount of fuel which is sent to the engine. A simple schematic (Fig. 5) shows how the throttle positions a spring which applies a force against a set of flyweights. When engine speed causes the weight force to overcome the spring force, the output rod will move to reduce fuel to the engine.

Should the operator ask for more power by moving the throttle to increase the spring force, the flyweight force will be overcome, and the output rod will move to increase fuel flow. On a large load demand, it is quite possible that the output rod would move in the open direction until it hits the adjustable movable stops in the limiting lever. Then the maximum allowable fuel valve opening is determined by compressor discharge pressure, compressor inlet temperature, and engine speed output linkages.

Should cdp increase, as during an acceleration, the bellows will expand, the right-hand side of the limiting lever will be raised, and the acceleration limit screw will permit the governor to move the fuel valve to increase engine fuel flow. When the requested new speed is reached, the governor will take over and regulate the fuel valve.

You may have noted that we cheated in this simple schematic. Actually, we want to multiply the cdp function by the speed and temperature functions. The schematic shows them to be additive. In practice, the output of the cdp bellows is connected to a logarithmic cam, as are the speed and temperature functions. The computer output is connected to an adding link which has two such cams as its inputs.

As we add logarithms, we actually multiply. So the computer output is the function we wanted—W_f or fuel-air ratio that is proportioned to W_a or mass air flow. However, it happens that the fuel flow requirements of a high compression-ratio engine cannot be accurately described by any simple linkage and use of a three-dimensional cam is necessary. The cam is rotated in relationship to speed and followers move across the cam in relationship to temperature.

The type 1910 will schedule fuel flow as shown in Fig. 6. All low-force servo valves are rotated, thereby increasing their sensitivity to input signals and decreasing their sensitivity to any containment which might be in the oil. A gear pump supplies Dow-Corning QF-1-0026 at 200 psi to the servo valves which boost the small input forces to high levels to overcome friction and loading forces. The output shaft to the fuel valve has 35 lb-in. torque available, for instance, to shear any dirt which might otherwise tend to jam the valve. This torque can easily be doubled by just raising the pump relief valve setting. The external fuel valve permits easy conversion to gaseous fuels.

Compressor inlet temperature is sensed by a gas-filled probe which produces a force proportional to temperature. This force is balanced by a spring which is loaded as the cam followers move across the cams.

Compressor discharge pressure is sensed by a bellows which produces a force proportional to pressure.

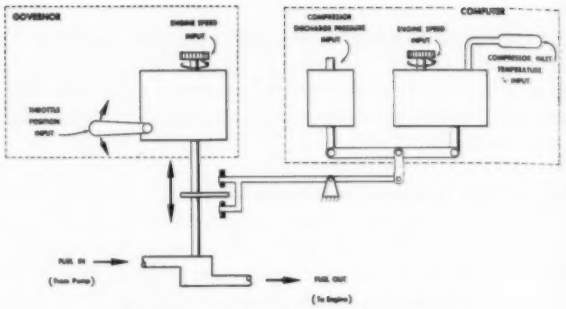


Fig. 5 — schematic of type 1910

Throttle movement rotates a cam which sets the force output of the governor speeder spring against the governor weight force. An isochronous governor is provided, which makes space available to change to a droop-type governor should a particular application make this desirable.

Free Turbine Application

A typical free turbine application would find the requested power turbine speed and actual speed being compared by a governor which sends an error signal to the throttle shaft of the gas generator control. The gas generator would then accelerate or decelerate until the engine airflow provided the requested free turbine speed. The computer would act in the normal way to protect the gas generator during speed transition. The free turbine governor can be chosen from a series of standard industrial governors including simple droop, isochronous, and load-sensing types; the choice being dependent on the transient load characteristics and requirements.

Type 1910 Status

As of July, 1961 the type 1910 has passed the component test stage and two units are now on test stands. We are presently running room-temperature calibration accuracy tests. Engine test should be run this fall.

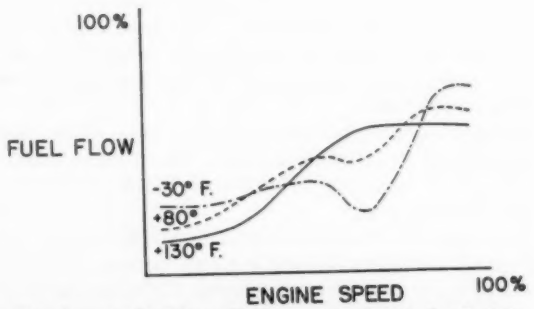


Fig. 6 — typical type 1910 acceleration fuel schedule

OBJECT of this paper is to present a different solution to the problems of surge encroachment and excess turbine inlet temperatures. These are always dangers when automatic starting and large upsets from low power points are required. This solution is closed-loop control of engine acceleration during engine speed transients in connection with a conventional speed control for normal operation. The closed-loop features of the acceleration control provide not only a simpler system, but also take into account any external change such as changes in fuel heating value and the like.

It may be seen that any limiting relationship defined by compressor surge and maximum turbine inlet temperature may be directly expressed in the form of excess torque. Engine inertia being constant, engine acceleration is tantamount to excess torque. It is then only necessary to sense engine acceleration, compare it to a desired acceleration limit, and then appropriately manipulate fuel flow to prevent the prescribed limit from being exceeded.

The fact that torque and correspondingly, acceleration, is independent of ambient temperature eliminates need for ambient temperature correction, subject only to the temperature correction to engine speed. This can be ignored except for very marginal cases.

Corrections required for nature of the fuel (heating value, density or temperature) in the scheduled control, particularly pertinent in the sensitive starting range, is not required because of the automatic compensation attained by use of closed-loop control. Similarly, independence of the condition of the starter battery is attained and, of growing importance, necessity for recuperator or regenerator corrective measures is eliminated. Provisions for normal limiting also provide for automatic starting. Multiple usage of components minimizes the number of control parts.

After mathematical derivation of several methods of sensing engine acceleration, a study of hardware to simulate the mathematical models was made. Also, study was made of results of a computer analysis where the acceleration limiter was used in conjunction with a conventional proportional integral control on both a single and split-shaft gas turbine.

Closed-Loop Acceleration-Limiting Control

Considering the acceleration sensor as a black box, its objective is to give an output signal corresponding closely to some function of the mathematical derivative of the input. Systems are in use where this signal is derived electrically. But this computer will use the same means used by the main body of the control—hydromechanics. Design advantages such as elimination of sealing problems and more advantageous force levels make an entirely hydro-mechanical control attractive.

Fig. 1 is a schematic of one concept of closed-loop acceleration-limiting control suitable to a split-shaft gas turbine. The power lever directly controls the gas generator speed with free-turbine speed not being used as a control parameter. Such might be the case for a gas turbine driving a pump in which power requirement is proportional to speed and desired power is obtained by setting gas generator speed.

Steady-state interrelationships of power demand, gas generator speed and lever position are represented by the cam on top of the power lever. This acts on the lower spring of the double-spring system. The free-turbine speed signal would be used only as an overspeed shutoff but this was omitted from Fig. 1, as was the turbine inlet temperature limiter conventionally used. This was done for schematic simplification.

The force balance between speed sensor (N_G) and equivalent spring constant produces a displacement that is introduced to the small double-spring system and compared to a desired power point as defined by the previously-discussed cam. It should be noted that at any absence of power error or steady-state condition, point

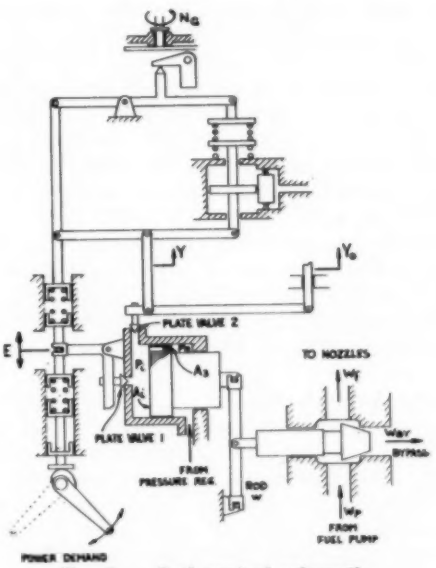


Fig. 1 — Fuel control schematic

E always assumes the same vertical position. Any displacement of point E from this position, displaces the right-angle link and changes the effective flow area of plate valve 1, thus acting on the integrator piston.

The fuel control valve is of the bypass type. An increase in fuel flow would call for the integrator piston to move towards the right. Bypass valve displacement depends on integrator piston movement alone in this case, the other side of summing rod W being fixed. The fixed side of the summing bar may be the acting point of a proportional piston if desired.

For an integrator piston geometry where effective area of the left side of the piston (A_1) is twice what it is on the right side, steady state would prevail if the areas of plate valves 1 and 2, working on speed and acceleration errors respectively, would be equal to A_3, area of the hole in the integrator piston. Pressure P_1 would be equal to one-half the regulated pressure because of the area

ratio. The stroke of plate valve 2 is the difference of Y (displacement proportional to acceleration output) and Y_0 (a displacement proportional to limiting acceleration). Plate valve 2 is closed at steady state as Y, the measured acceleration, is zero while the limit Y_0 is finite.

For clarification, a positive transient will be discussed with emphasis on how the two plate valves function. At the low-power steady-state point, plate valve 2 that is actuated by acceleration is closed and plate valve 1 is open, keeping the engine on speed. As more power (corresponding to a higher gas generator speed) is requested through a change in power lever position, the error between desired and actual speed closes plate valve 1. Pressure P_1 increases and the integrator piston and fuel bypass valve move to the right. Fuel flow into the engine is increased and the engine accelerates.

When actual acceleration approaches limiting acceleration, plate valve 2 opens and controls acceleration until the new desired speed is reached. As soon as the speed error approaches zero, plate valve 1 opens, reducing acceleration, and plate valve 2, in trying to increase acceleration, saturates in a closed position. The only time that both plate valves are open concurrently is at the end of a transient. Therefore there is very little inter-action between the speed and acceleration error controls even though they both use the same integrator piston to provide the force necessary to move the fuel bypass valve.

The limiting demand does not have to be a constant as shown in Fig. 1 but may be varied by any engine variable or ambient condition. Variation of acceleration demand by controlling gas generator speed is most convenient because of signal availability.

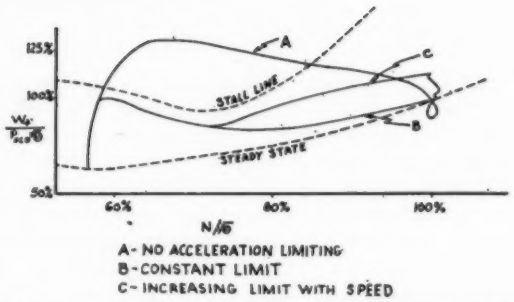


Fig. 2 — power upsets using integral and acceleration limiting control.

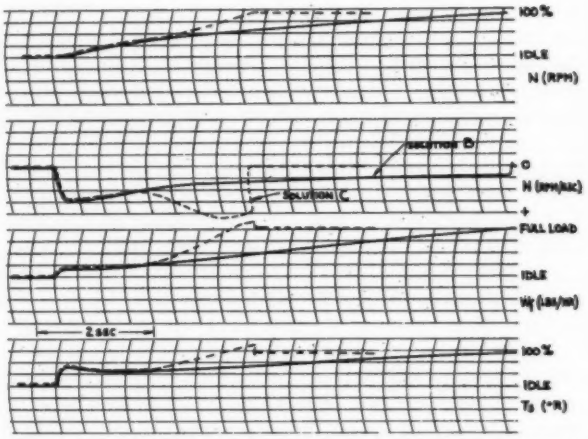


Fig. 3 — B and C transients (see Fig. 2) with plots of speed, acceleration, fuel flow and turbine inlet temperatures, respectively.

Computer Analysis Results

Some results of a computer analysis of the engine under the type of load discussed and with control as represented in Fig. 1 are shown in Figs. 2 and 3. Fig. 2 is a plot of corrected gas generator speed versus corrected fuel flow over pressure, both expressed as percentages. Initial steady-state point is at approximately 60% of design gas generator speed and idle or zero output power.

Transient A is a trace of a solution in which the acceleration limiter was not operative; transient B has the accelerometer in the control with a constant demand; and in C the demand increases linearly after approximately 78% speed. Cut-in point of increased demand of trace C was chosen in cognizance of the narrowest band between corrected steady-state and surge.

Fig. 3 shows B and C transients with plots of speed, acceleration, fuel flow, and turbine inlet temperature on channels 1 to 4, respectively. Fuel response of transient B (constant demand) takes approximately 8 seconds. By varying demand, (transient C) total time may be cut to 3-3/5 seconds.

Lucas-Rotax fuel controls

CONTROLS and control techniques to be covered are suitable for gas turbine engines as would be used for road transport vehicles or stationary equipment.

Control requirements for automotive gas turbine engines are generally common to all gas turbines, although some special features do occur. Basically, the engine requires starting; has to be capable of being accelerated to any speed; to be controlled at any selected speed; and the control must be capable of adjusting to load demands automatically. In addition, of course, proper means of shutting down are required.

Individual Control Functions

Fuel Sprayer—choice of fuel spraying or atomizing system is dependent basically upon the range of fuel flows which must be provided. On present applications for stationary drive purposes such as generating systems, water pumps and so forth, the ratio of maximum to minimum fuel would not exceed something like 3:1. In such a case a Simplex type of sprayer would be suitable. These sprayers have an inherent square law characteristic. Fuel is atomized by rotational velocity imparted to it in a conical chamber in which it is fed tangentially.

For application to automobiles, and with the adoption of heat exchangers, the range of fuel flows required has increased appreciably, well beyond a reasonable application of the Simplex sprayer. We therefore find that Duplex spill or air-assisted types of sprayers are employed.

The Duplex type of sprayer consists essentially of two Simplex sprayers arranged concentrically in a single unit so that separate tangential feeds are provided into the conical swirl chamber. In this way an overall characteristic can be derived in which a fuel flow range of the order of 10:1 or so can be satisfactorily accomplished with a minimum pressure of 100 psi and a maximum pressure of the order of 1200 psi. The atomizer is provided with a changeover valve that proportions flow through the two parts of the atomizer.

Starting and Acceleration Controls—Linear flow-speed characteristic of a fixed displacement pump can be used to provide an acceleration control and, to some extent, a starting control. In general, this is easier to accomplish with a piston-type pump due to its linearity at lower speeds.

If use of the pump characteristic as the acceleration control can be achieved, considerable advantage from the cost point of view is obtained.

A simple form of acceleration control employing the pump characteristic has been developed. A bypass orifice around the pump is used to reduce the pump effective output. This bypass orifice is opened or closed by a signal from a tachometer generator and can be arranged to avoid the stall line of the engine.

Governing—For automotive purposes, control of engine speed to within 2% is considered acceptable and simple spill governors are adequate. The top-speed governor is normally arranged in the free turbine shaft to limit maximum speed and an extra safety device in the form of an overspeed trip is also fitted. It is preferred to eliminate all rubbing parts from the governor elements.

For many years our aircraft control valves have employed strip hinges and Fig. 1 illustrates an extension of this principle to a governor. In this governor the control valve is driven by the rotating strip hinge assembly so that there is no hysteresis at the valve itself. Furthermore, the hinges themselves operate with negligible hysteresis and with no friction.

Change of governor datum is effected by axial movement of the stationary shaft. This feature eliminates necessity for employing thrust pads for adjustment. Extensive endurance tests of this form of governor have shown extremely promising results and the construction is potentially cheap.

Temperature Controls—Control of exhaust gas temperature has been achieved by two systems. The earlier system employed a mercury vapor temperature control. This consists of a mercury boiler arranged in the exhaust cone. It generates a pressure, proportional to the temperature, fed to a bourdon tube, the output of which is used to control the fuel valve.

Another simpler and somewhat cheaper method has been to utilize the differential expansion between dissimilar materials. Earlier forms of this device employed

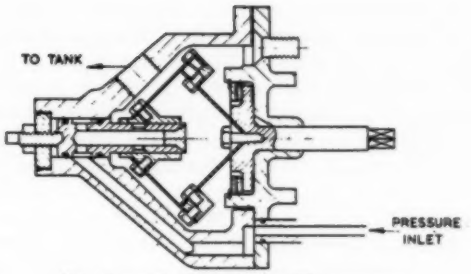


Fig. 1 — leaf spring spill governor

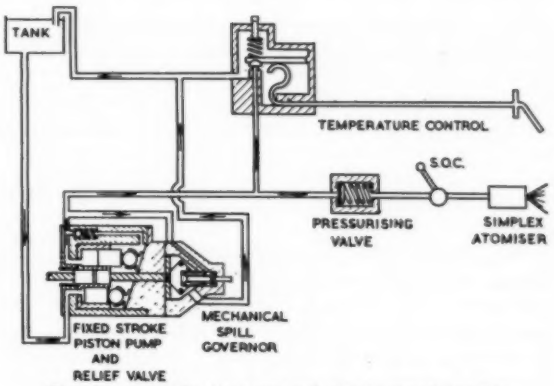


Fig. 2 — simple fuel system; single spool engine

quartz and nimonic, but later developments have employed nimonic and tungsten. The latter form possesses inherently less thermal lag. Both types of temperature control described avoid the existence of fuel near the exhaust cone.

Typical Control Systems

Simple Fuel System—Fig. 2 illustrates the basic elements of a simple control system. For simplicity, Simplex atomizing has been considered. The basic system consists of a fixed-stroke axial piston pump providing fuel to the Simplex atomizer via a shutoff cock. A pressurizing valve is interposed in the system to ensure that adequate system pressure is maintained for satisfactory operation of the spill control valves.

The mercury vapor temperature control is used to control acceleration of the engine and a mechanical spill governor mounted on the pump shaft is used to control the speed of the engine. This control could be made of a variable datum type, although the actual drawing shows a single-speed governor.

Automobile Fuel System—Fig. 3 shows a suggested form of gas turbine fuel system suitable for automotive purposes. In this system air atomization of fuel has been adopted and a suitable air compressor is provided which is driven by a separate electric motor. With this system, pressures of the order of 100-200 psi only are required and as a consequence a gear-type pump may be employed. The shutoff cock is operated electrically so that it may be linked into the starting system.

A variable datum governor of the mechanical-spill

type is provided to control the amount of power available to the free turbine and is linked directly to the accelerator pedal. Because of the low system pressures employed, an acceleration control of the double diaphragm type is employed to provide direct control of the system pressure by means of the blower pressure. Where the altitude range of the engine is considerable, the introduction of a bellows into the fuel-air ratio control can be provided.

Temperature control of the differential expansion type is shown. In this case the temperature control bleeds blower pressure into the area between the diaphragms of the acceleration control alone, arrangement depending on the particular characteristic of the engine.

Fig. 3 also shows an overspeed trip valve of the shaft-governor type. This is fitted directly on the free-turbine shaft so that, in the event of a shaft or transmission failure, rapid shutdown of the engine occurs without incurring the danger of a free power turbine failure.

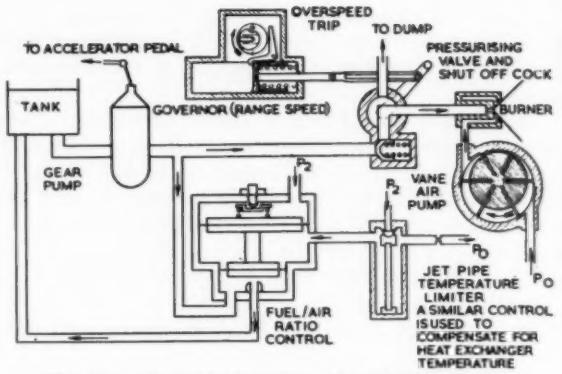


Fig. 3 — air assisted system, free turbine engine

de Havilland control for Gnome engines

THE de Havilland Engine Company has built the Gnome helicopter engine in accordance with license agreement with General Electric, the Gnome being their version of the T58. Control for the Gnome is of the electric computer type thereby being considerably different than that on the T58. Both the T58 and Gnome controls have the same basic objectives.

The de Havilland control is specifically built for the Gnome to make best use of this free-turbine engine for the helicopter application. By providing the engine with fully automatic control, the pilot is relieved of all responsibility for regulating fuel. He can make whatever changes he likes to his flying controls knowing that the engine will always respond rapidly to the load changes he applies and will hold the rotor speed he has selected. Furthermore, the control assures that the engine will never be allowed to operate outside its safety limitations.

Fuel Control Components

Following is a breakdown of all the elements in the control system:

- Fuel System
  - Centrifugal filter
  - Priming filter
  - Fuel pump and flow control unit, comprising . . .
    - Fuel Pump
    - Rotary throttle
    - Double-acting shut-off cock
    - Pressurizing valve
    - Relief valve
    - Flow control mechanism
    - Pressure speed function generator
    - Top-speed governor
    - Idling bypass
  - Fuel-cooled oil cooler
  - Flow divider
  - Fuel manifolds (2 pairs)
  - Burners (16)
- Electric Control System
  - Computor
  - Actuator
  - Stator Vane Control and Actuator Unit
  - Signal Generators
    - Gas generator speed tachometer
    - Free (power) turbine speed tachometer
    - Engine intake temperature thermistor (for computor)
    - Engine intake temperature bulb (for stator vane control)
    - Free (power) turbine inlet temperature thermocouples (8)
  - Protective Control
    - Free (power) turbine overspeed trip governor

General Description of Control

Control requirements for a helicopter engine differ quite considerably from those for other aircraft, largely due to the frequent and sudden power changes that are demanded, coupled with the necessity to maintain helicopter blades rotating at a substantially constant speed throughout the flight. The free-turbine configuration of the Gnome is ideally suited to this purpose as the output shaft speed is independent of power level. Power level thus becomes a function of gas generator speed which, because of low compressor inertia, can be changed very quickly by altering fuel flow into the combustion chamber.

Engine Weight Without Gearbox

Engine net dry weight	300 lb
Tachometers	4 lb
Starter	16 lb
Computer (aircraft-mounted)	18 lb
Total	338 lb

Engine Ratings at Sea Level

Item	2.5 min	1 hr	Continuous
Shaft hp	1350	1250	1050
SFC	0.168	0.624	0.641
Power Turbine rpm	19,500	19,500	19,500
Gas Generator rpm	26,750	25,930	25,300

If rotor blades are to be kept rotating at constant speed, power demand from the engine largely depends on the blade pitch. Whenever a change in flight path is made, this must be accompanied by a change in engine power.

With the Gnome, control of the fuel throttle is placed under the command of an electric computor. The pilot selects the rotor speed at which he wishes to operate and the computor automatically maintains this speed within the limits of governor droop, irrespective of load changes that are applied during flight.

The engine is fitted with a conventional Lucas fuel system which consists of a variable-stroke piston pump delivering through a simple flow control throttle valve and shutoff cock to the burner manifolds.

Stroke of the pump is servo-regulated hydraulically to maintain a set pressure drop across the flow control throttle and this pressure drop is varied with air-intake pressure so that, for any throttle position, the fuel flow is reduced with altitude approximately in accordance with the engine's requirements for a constant gas generator speed. The throttle itself is geared to a small electric motor which receives all its driving signals from the electric computor.

The computor operates off a 24-volt d-c battery and receives input signals of free-turbine speed, gas generator speed, air-intake temperature, and inter-turbine temperature, together with the pilot's requirements.

The latest design and constructional methods are used in the electrical circuitry. Wiping contacts and moving parts, other than those in the motor, are avoided and great care has been taken to ensure reliability under all operating conditions. Magnetic amplifiers are used for control, transistors for the power supply. The whole is housed in hermetically-sealed casings and proof-tested under artificially-simulated extremes of climate and vibration.

The selector lever in the cockpit is linked mechanically with a corresponding lever on the computor and enables the pilot to select a rotor speed within the range 85% to 100%. The computor measures the error between actual rotor speed and that selected, amplifies the error signal and sends forward a correcting signal to the throttle motor. This is caused to rotate at high speed to make the necessary fuel flow change unless restrained by one of the limiting controls.

Conclusion

Comments by de Havilland on this subject appear to be a fitting conclusion.

"As you are probably aware, de Havilland developed this engine control system to overcome the difficulties associated with matching a full hydro-mechanical engine control system with the widely differing characteristics of various helicopter dynamic systems. Experience has proved the many advantages of the de Havilland system especially when full-authority governing is required."

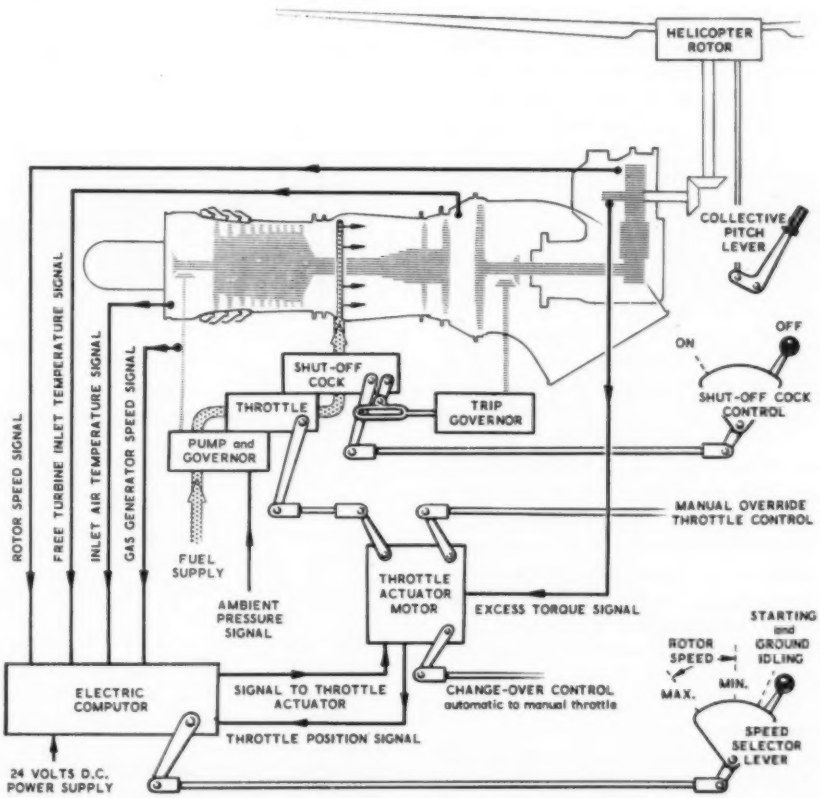
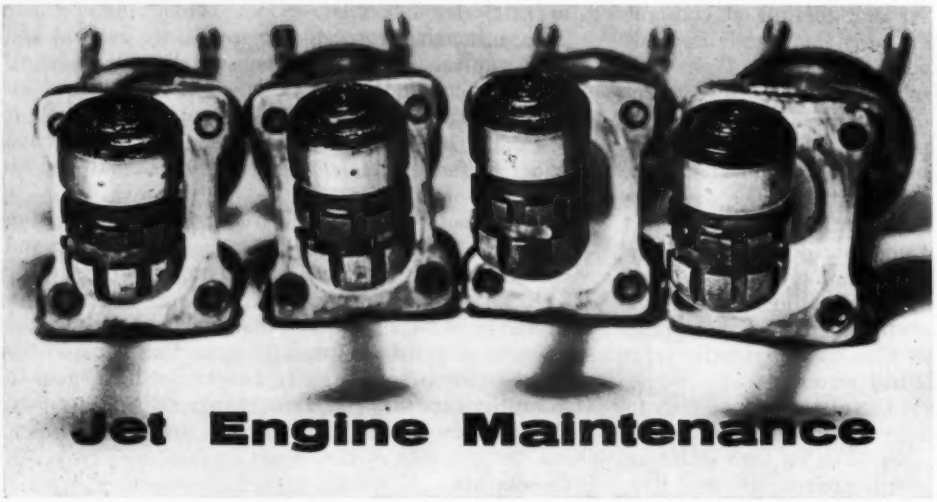


Fig. 1 — simplified diagram of fuel and control system



Typical condition of burners that remains the same regardless of operating time.

Jet Engine Maintenance

by J. T. Dyment
and J. J. Eden
Trans-Canada Airlines

This is an abstract of SAE paper 345C "Trans Canada's Experience with the Rolls-Royce 'Conway' Turbine Engine" presented in New York, April 4-7, 1961

One year of DC-8 operation and over 42,000 Conway engine hours have been accumulated by Trans-Canada Airlines. It is now opportune to review our initial experience with this new class of gas turbine engine. The Conway is one of the new turbofans, utilizing the bypass principle, of the type now appearing on the American market.

This RCo12 Conway engine as used in TCA operation has a average take-off thrust of 18,000 lb at ISA conditions at sea level. This increases to 20,000 lb as colder conditions are encountered. These thrusts are the highest being achieved by any gas turbine engine in civil flight operation to date.

Combustion in these engines is very clean. Observers of our DC-8 operation may have been surprised by the lack of smoke from the engines. The combination of high-pressure fuel system and fuel burner design (particularly when operated on JP-4 fuel) is providing a remarkably clean, carbon-free operation.

Another feature is that the Conway engine is fully adaptable to fuels of different specific gravity without need for adjustment. Gravity changes only require a corresponding change in the calculated fuel loaded for a given flight.

One problem that has been more severe than anticipated has been that of bird ingestion. A great deal of work and planning is required to combat the bird ingestion problem. TCA has experienced a large number of cases of bird ingestion, to the point that nearly all engines in the fleet are believed to have ingested a bird at some stage of their operation. As it is now, the Conway engine has coped reasonably well with ingested birds.

Overhaul Life Development

TCA's basic philosophy is that time between overhauls of an engine and the period considered maximum service life of its components should be increased as fast as proof becomes available that no hazard will exist due to the time extension. Failure not related directly to service time should not limit time extension between overhauls.

Fig. 3 shows the rapid overhaul life development achieved with the Conway engine. By means of the planned sampling program, as shown in the figure, TCA reached 1500-hr on its sample engines as of last March. The gas turbine engine is potentially adaptable to very high overhaul life as compared to piston engines and a philosophy of engine life development matched

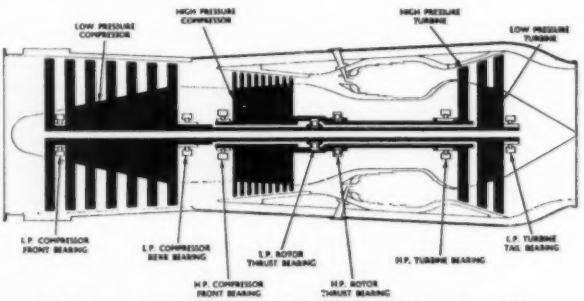


Figure 1—Main rotating assembly of Conway engine.

to the potential of this type engine is required.

TCA believes that the programs as practiced by the airline and approved by the Canadian Department of Transport permit exploitation of potential engine overhaul life without increasing risk of failure. It believes in the validity of a small number of samples seen at short time increments such as 100-hr. In general, on the gas turbine engine, the airline is probing for component total-time limitations rather than limitations which could be linked with time between overhaul.

Development of the engine to 1500-hr overhaul life

EDITORS NOTE: Certain information TCA has learned would be well for other than aircraft operators to take an interest in if they are not doing so already. A good example is the use of spectrographic oil analysis.

within the period of one year of operation is a sign of the potential of the Conway engine, as well as confirmation of the validity of the program. Nothing is evidenced in the engine to date which could limit overhaul life development. Unless something unexpected occurs, TCA proposes to continue the life development program by following the sampling program with a continuous-type trial, 2000-hr overhaul life being the immediate objective.

Here are some details of current approaches and programs.

Preventative Failure Analysis

Taking individual phases one-by-one, it is possible to detect incipient failures and isolate their causes.

Vibration—Introduction of big jet aircraft has increased the effect on operation of unexpected component failures. Techniques for recognizing problems at the incipient stage—and also simplification of trouble-shooting methods—must be improved. In the field of preventative engine failure analysis, introduction of vibration detection equipment to monitor engine vibration should be helpful. The approach is practical: for example, we have over 2000 operational hours on one set of airborne vibration equipment without failure in the system's operation.

Metal-Detecting Plugs and Filter Inspection—The oil system of the engine has primarily been designed to provide lubrication and cooling to bearing surfaces. With application of other techniques, the oil system can be used as a means of indicating incipient component failure. Metal-detecting plugs have been used in piston engines (such as in the Wright Compound Engine) to substantial advantage and TCA has tried to follow this example in the case of the Conway engine.

A simple hardware-type of magnet has been installed in the scavenge screens of engines that were suspect due to a buildup of metal in the pressure filter. Even a short period of running with this simple magnet installed has either confirmed the health of the engine or has pinpointed the bearing as having an incipient failure.

Magnets installed in individual scavenge lines rob the main pressure filter of the metal deposit, necessitating individual scavenge filter inspection. A more refined system is required. TCA's approach to such a system is to use a Lisle detecting plug installed in the scavenge filter to permit external measurement of metal deposit.

Engine oil systems should be so designed that metal detecting plugs on which both magnetic and non-magnetic particles will deposit are installed in scavenge lines. This deposit should be measurable by an external means which indicates the degree of metal collected. It should be possible to do this without disturbing the oil system of the engine.

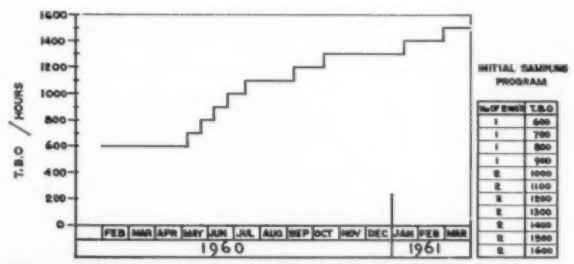
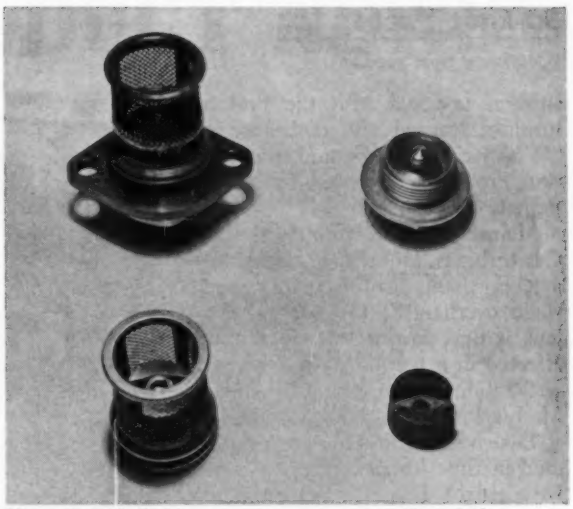


Figure 3—rapid overhaul life development achieved with the Conway through the planned sampling program.



Magnets installed in scavange screens confirmed the health of or indicated incipient bearing failure.

In operation of the Conway engine, TCA has also found that individual or isolated pressure filter checks are not reliable in determining the state of the engine. We have, therefore, resorted to systematic collection of metal deposits found in the filter.

A sample board is maintained for each individual engine. On it, the packaged metal sample, as collected at filter checks, is stored. Here, the history of metal buildup can be traced and action taken as required for each individual engine. The *rate* of metal buildup is often more significant than the actual amount of metal found. As the pattern of metal loss and "thresholds" of acceptability are established, say from a bad engine, this data can be applied to show incipient bearing failure in others.

Just prior to passenger service, an in-flight shut-down due to a compressor bearing failure was experienced. The programs described above were applied at that time and TCA has since removed a total of 24 engines for suspect metal condition without a further in-flight shut-down. In addition, incipient failure was recognized at such an early stage that all these removals could be scheduled into our main base, achieving a minimum of operation inconvenience.

Out of the 24 engines, 20 removals were substantiated by finding incipient stages of bearing spinning or break-up. Only in four cases were the removals subsequently unsubstantiated.

It is only due to collection and analysis of filter deposits and use of metal-detecting plugs that this performance has been achieved without in-flight shutdowns.

Spectrographic Oil Analysis—In addition to the above work linked with the oil system, TCA has followed a research program into the possible use of spectrographic oil analysis to give warning of incipient bearing problems. Background experience is not extensive

(*Continued on next page*)

50-knot Yacht . . .

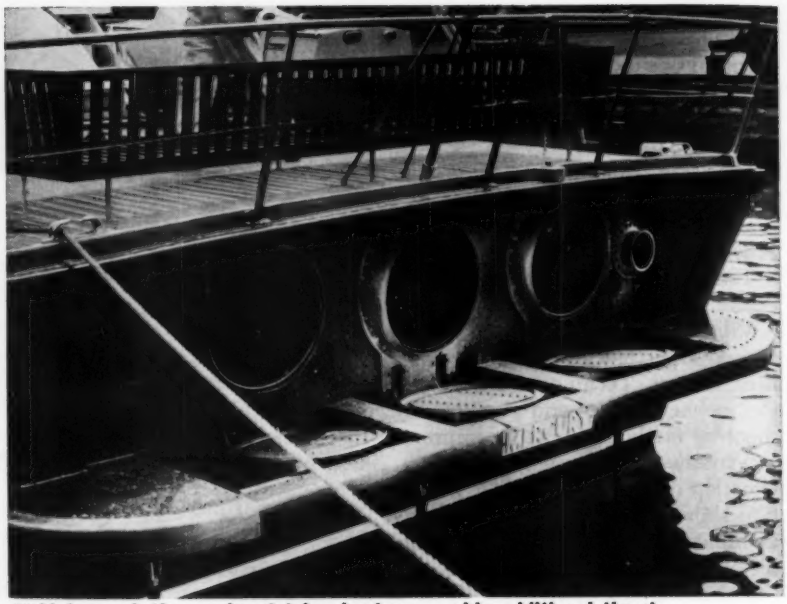
(Continued from page 21)

airliner, powered with the Proteus turbines, earned the nickname of "Whispering Giant" and the Marine Proteus has proved to be extremely quiet at sea.

Maintenance is extremely simple. Gas turbines, in any case, suffer less defects than piston engines and, when overhaul of the Marine Proteus is due, engine change can be effected in a few hours in a normal installation. The overhaul life of the Marine Proteus is about 2000 hours.

Two Marine Proteus engines are used in the Vosper "Ferocity" class Fast Patrol Boats, which, though smaller than the three-engined Brave class boats, have a similar performance.

The three marine Proteus turbines are shown in the engine room of the "Mercury". Controls for these turbines are compact and readily accessible. No warming up period is required so that full power is instantly available at all times. At top speeds additional thrust is provided from the stern exhaust of the gas turbines.



At high speed, three exhaust tubes in stern provide additional thrust.

Jet Engine Maintenance . . .

(Continued from preceding page)

to date. However, some significant conclusions can be drawn. For the Conway engine, iron content as seen in spectrographic analysis of the oil parts per million can be related to bearing condition.

Fig. 5 shows three clear cases. The first graph shows iron content in the oil of an engine which operated to 1000-hr and was then overhauled. The bearing condition remained at a level below four. The second graph shows the only case of in-flight failure. It is seen that the iron content of the oil had risen as high as 10 some 100 flying hours before the bearing actually failed.

In the third example, iron content had increased to 10 and continued to show a high level. The engine was removed at 443 hours because of metal indications in the filter and it was found that the front bearing was spinning on its shaft. This was producing the fine steel particles.

From the experience gained, TCA is sufficiently encouraged to believe that by further work in the area of spectrographic or similar scientific oil analysis, warning can often be gained of incipient problems in time to take preventive action.

Summary

TCA believes that it has now passed the hump of problems with the Conway. As soon as it can complete the rectifications now planned by Rolls-Royce for each of the problems, it will have an engine that should gradually approach the Dart in its record of reliability.

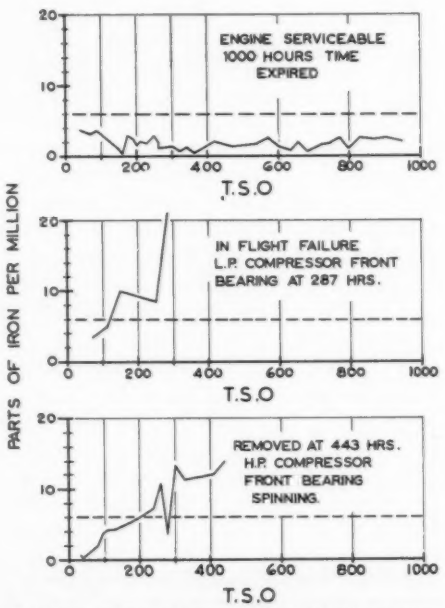


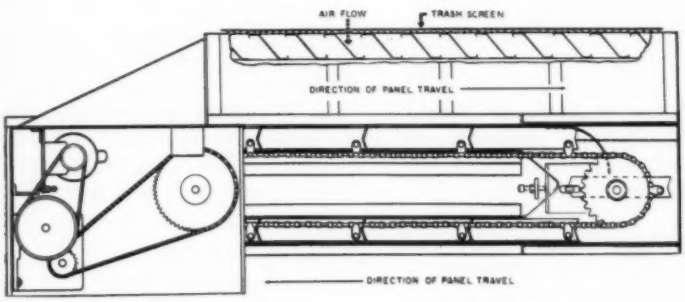
Figure 5—Three cases of iron content of oil as seen by spectrographic analysis relating to bearing condition.

GT PRODUCT NEWS

Electronic Gaging

Designed to eliminate errors in reading and recording and to permit new flexibility in gaging, a new line of electronic gaging apparatus has been introduced by Winslow Manufacturing Co. This machine, for example, reads out 24 different gage points, showing the location and the variation in lighted numerals one inch high. In addition, this machine prints this information on paper tape.

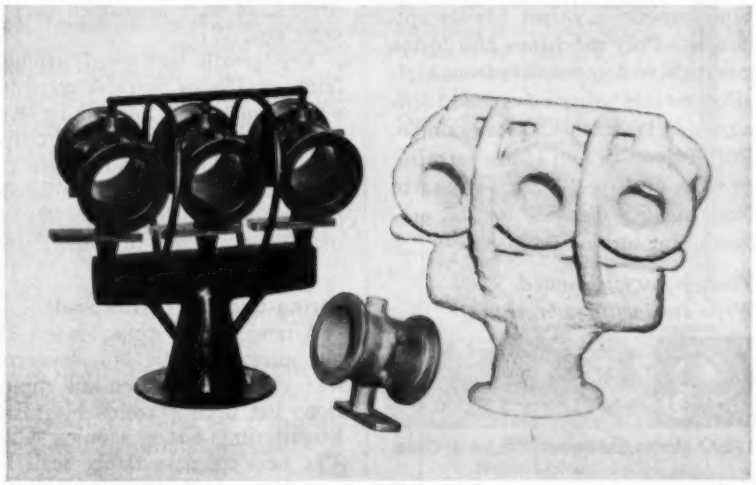
1120



Automatic Air Filter

A line of Automaze HD heavy-duty automatic air filters has been introduced by Air Maze Div. of Rockwell-Standard Corp. for use on installations such as air intakes of large gas turbines in stationary power plants, and similar applications requiring uninterrupted service over long periods with no maintenance. Wide capacity range is offered.

1121



Aluminum Castings

Misco Precision Casting Co., a division of Howe Sound Company, has entered the aluminum casting field. They have adapted their Mono-Shell process to the production of these castings. Shown are Misco aircraft valve bodies of 356-T7 aluminum alloy. Right to left: wax pattern assembly, Mono-Shell ceramic-dip slurry after firing, and finished casting.

1122

POLY

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Anti-Icing Additive Injection System

A new high-capacity precision additive injection system designed for blending anti-icing fluid with aircraft jet engine fuel was announced by Chandler Evans Corp.

Known as the Ceco Liquid Ratio Controller, the unit (39 in. x 23 in. x 26 in) is capable of handling fuel flow ranges up to 10,000 gallons per

minute and can control pre-selected additive injection ratios with an error of less than 2%. It can be adapted to a wide variety of chemical processes and fluid blending operations.

The LRC is ideally suited for use during truck or tanker loading operations or for blending at the refinery.

1123

Free Machining Stainless Steel

Universal-Cyclops Steel Corporation, Bridgeville, Pa., announces the commercial availability of a new free machining chromium-nickel stainless steel, designated Uniloy 303MA. This new grade is the most important development in a free machining stainless steel since they were developed over 25 years ago.

The greatly improved machinability of Uniloy 303MA compared with regular free machining AISI Type 303, permits increased output of machined parts and longer tool life, resulting in considerable dollar savings for plants now using regular Type 303 for machined parts.

1124

Spring-Loaded Teflon Seal

A new line of spring-loaded Teflon pressure seals for cryogenic, fuel, oil, gas and chemical applications has been developed by Raco Engineering, Santa Monica, Calif. The new standard flange seals feature a stainless steel spring insert which acts as a compensating pressure on the Teflon seal in temperatures ranging from −420°F. to +500°F. The spring insert is said to provide initial sealing at zero pressures, as pressure increases sealing force increases. The spring also compensates for dimensional changes resulting from tolerance variations, thermal expansion or contraction and cold flow of the plastic.

1125

Air Melted WI-52 Superalloy

"Of the air melted group of superalloys, WI-52 has the best known high temperature properties. Stress rupture life, creep strength and thermal shock resistance of WI-52 are superior to other cobalt base alloys," this according to WaiMet Alloys Co., who make the WI-52.

Curves have been developed by Bristol Siddeley Engines, Limited, Bristol, England, illustrating that nickel base vacuum melted alloys have only very slightly higher stress rupture properties in the 1800 to 2000F temperature range than the cobalt base, air melted WI-52 superalloy. Where cost is a factor the WaiMet Alloys Company, Division of Howe Sound Company recommend the use of WI-52 superalloy.

1126

Lycoming T53-L-9 Engine Completes Test

Successful completion of the official 150 hour military qualification test by the Lycoming T53-L-9 helicopter engine was announced by Avco Corporation's Lycoming Division, Stratford, Connecticut. The qualification test for the 1100-hp L-9 was especially rigorous in that approximately 50% of the endurance running was performed at military-rated turbine temperatures or above, and at powers in excess of 900-shp. All military power running was at takeoff turbine temperature and all normal power running was at military turbine temperature, thus qualifying the engine to provide military and normal power up to an 80° F day.

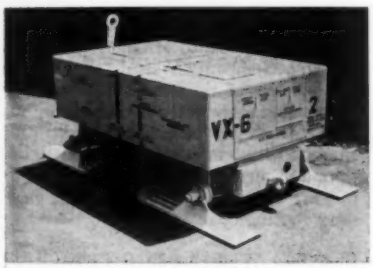
Test results, which in all cases met

or exceeded guaranteed specifications, have been accepted by the Air Force. Officials of the Federal Aviation Agency also witnessed the test as part of the requirement for commercial certification of the engine. The T53-L-9 will be used to power versions of the Army's Bell HU-1B helicopter along with the more advanced HU-1D models. An initial production contract for the engines has already been received by Lycoming.

1127

Power Sled for Antarctic Ground Support

Ground Power Sled eliminates many support problems incurred in sub-artic weather during jet aircraft starting and pre-flight checkout. One of five delivered to the U. S.



Navy Air Development Squadron, stationed in the Antartic, the unit is produced by Garrett's AiResearch Manufacturing Division of Los Angeles and is powered by an AiResearch GTCP 100-1 gas turbine engine which produces 120 lbs/min of pneumatic power; 400 cps; and 28 volt dc power.

1128

Turbomeca Shaft-Turbine's Available From CAE

TURMO III-C (1184-hp), ASTAZOU II (522-hp), BASTAN IV (916-hp) ARTOUSTE II-C (400-hp) Turbomeca Shaft Turbine Units are available from Continental Aviation & Engineering Corp. under License Agreement with Societe Turbomeca of France. These engines, in addition to Continental's own series of engines, provide power coverage in a range from 400 to 1200-shp in both free and connected turbine models.

These Turbomeca units have been approved by the French Air Ministry and are presently powering aircraft that are in flight-test or production in Europe.

1129

New All-Metal Seal

Development of new series of its BAR-X-all-metal seal for use in dynamic applications, such as reciprocating and rotating sealing functions, was announced by Wiggins Connectors.

The company reports the new seal performs at temperatures from −425°F to +1200°F and pressures from extreme vacuum to 6000 psi, plus. According to Wiggins, the seal requires low force installation and has practical breakout torque requisites for shaft seal applications. Special materials are used to provide reliable long life.

1130

3 MW Mobile "Power Package"

An advanced type of electric generating equipment, 3 MW "pocket power station on wheels", is being produced at Bristol Siddeley at Ansty, near Coventry, England.

This compact, self-contained turbo-generator, powered by an industrial version of the Bristol Siddeley Proteus gas turbine engine has an "unrivalled" background in aero, marine and industrial fields.

For mobile use, the equipment's aluminum body, divided into three compartments, on its heavy-duty welded chassis, is easily transportable by tractor and eight-wheeled semi-trailer. If the "power package" is to remain on a permanent or semi-permanent site, there is no need for foundations as the chassis is rigid and provided with six levelling jacks. Air intake and exhaust systems are silenced to a noise level acceptable for residential areas.

1131

High Temperature Metal Hose

Universal Metal Hose Company, Chicago, Illinois offers an All-Metal Bronze and Carbon Steel Flexible Connector, the "UC3", designated for conveyance of gases and fluids

under temperatures up to 750°F. Stainless Steel versions are suitable for temperatures of 850°F and 1400°F. The "UC3" Connector features a braided outer cover and a corrugated inner tube for combined flexibility and extra strength.

1132

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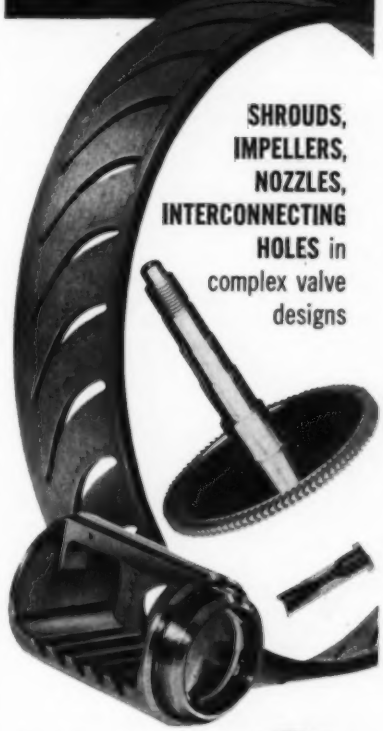

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GT PATENTS

By J. W. Sawyer

FUEL CONTROL MECHANISM (2,963,860) 20 CLAIMS Stanley G. Best, Manchester, Conn., assignor to United Aircraft, Corporation, East Hartford, Conn.

ELECTRONIC FUEL CONTROL APPARATUS FOR AN ENGINE (2,963,861) 18 CLAIMS Herbert C. Waterman, Chicago, Ill., assignor to The Bendix Corporation.

PRESSURIZED SEAL (2,963,268) 6 CLAIMS Hamad Jasper Smile, Reading, and Elmir E. Paulson, Maderia, Ohio, assignors to General Electric Company. A pressurized chamber-like structure between a rotating and stationary element which may form a pressurized seal and an air bearing.

GAS TURBINE FUEL CONTROL SYSTEM FOR PREVENTING COMPRESSOR STALL (2,989,850) 10 CLAIMS Daniel G. Russ, Hatboro, Pa., and James M. Eastman, South Bend, Ind. assignors to The Bendix Corporation. One object is to provide a control system which will schedule fuel very close to temperature and stall limits of the engine without the necessity for actually sensing temperature.

FLAME STABILIZATION BY CORONA DISCHARGE (2,963,864) 5 CLAIMS Robert A. Gross, Huntington, N. Y., assignor to Fairchild Engine and Airplane Corporation, Hagerstown, Md.

SUPERCHARGER USING CENTRIPETAL FLOW COMPRESSOR AND CENTRIFUGAL FLOW TURBINE (2,990,104) 6 CLAIMS Vladimir H. Pavlecka, Pacific Palisades, Calif. Provide a unit utilizing a multi-stage centripetal flow compressor and a multi-stage radial flow turbine, the compression stages being directly connected to the turbine stages. The compressor and the turbine stages are integrated into unitary rotors mounted on air bearings so that the entire structure does not have any central shaft or shafts for supporting the multi-rotor structure.

REGENERATIVE HEAT EXCHANGERS (2,987,885) 5 CLAIMS James Hodge, Farnborough, England, assignor to Power Jets (Research & Development) Limited, London, England. A fuel control arrangement in plant incorporating a regenerative heat exchanger matrix comprising a fuel control valve, a mechanism for changing the matrix from a position in a hot fluid path to a position in a cooler fluid path and an operative connection between the mechanism and the valve to control the fuel input to the plant in accordance with changes in the rate of heat transfer to the fluid flowing through the matrix.

TURBINE SPEED CONTROL APPARATUS (2,988,326) 8 CLAIMS James C. Wise, Euclid, Ohio, assignor to Thompson Ramo-Wooldridge Inc. A speed-limiting control for turbines used to drive a load subject to sudden variations from substantial values to very low values, and particularly for a turbine used to drive an aircraft fuel pump.

ROTORS FOR MULTI-STAGE AXIAL FLOW COMPRESSORS OR TURBINES (2,988,324) 5 CLAIMS Michael J. Sutters, London, England, assignors to D. Napier & Son Limited, London, England. Rotors for multistage axial flow compressors or turbines of particularly light construction. The blades in each of at least two adjacent rows of rotor blades have root portions provided with forward and rearward projections which enter holes adjacent to the peripheries of two parallel thin supporting discs which resist the centrifugal forces acting on the blade row, and annular driving members concentric with the rotor extend between adjacent blade rows and are provided with forward and rearward projections which enter holes in the adjacent supporting discs.

VARIABLE CONVERGENT/DIVERGENT JET PROPULSION NOZZLE. (2,989,847) 11 CLAIMS Rowan Herbert Colley, Sunny Hill, Derby, England, assignor to Rolls-Royce Limited, Derby, England. Invention comprises improvements in or relating to jet propulsion nozzles and provides an improved construction of convergent/divergent nozzle.

ANNULAR COMBUSTION CHAMBER WITH ROTARY ATOMIZATION OF THE INJECTED FUEL. (2,994,192) 14 CLAIMS Kar Eisele, Fellbach, near Stuttgart, Germany, assignor to Daimler-Benz Aktiengesellschaft, Stuttgart - Unterturkheim, Germany. Improvements in annularly-shaped combustion chambers of gas turbines or jet engines and consists essentially in that the fuel subjected to turbulence by the rotary atomization during injection is fed into the combustion air in this state of turbulence, and more particularly in that the primary combustion air and/or the secondary combustion air prior to mixing with fuel are set into rotation.

EXHAUST NOZZLE CONTROL FOR GAS TURBINE ENGINES (2,987,876) 5 CLAIMS Howard J. Williams and James E. Hurtle, South Bend, Ind., assignors to The Bendix Corporation. The invention relates to a control system for a gas turbine engine having a variable area exhaust nozzle.

SAFETY DEVICE FOR STARTER TURBINE (2,987,296) 6 CLAIMS John H. Ferguson, Jr., Sauquoit, N. Y., assignor to The Bendix Corporation, Utica, N. Y. Relates to high speed turbine starters and concerns means for braking and containing the turbine wheel when the bucket segments separate at a low strength section.

ENGINE STARTING SYSTEM (2,986,005) 6 CLAIMS Jack D. Dudley, Belle Plaine, Kans., assignor to Boeing Airplane Company, Wichita, Kans. It is an objective of the invention to provide an accumulator and associated pressure controls on the gas side of a cartridge-energized system that is adequate to store up energy of sufficient magnitude to start an aircraft turbojet engine in a short starting cycle.

BLADED WHEELS FOR COMPRESSORS, TURBINES, AND THE LIKE (2,986,375) 6 CLAIMS Edward A. Stalker, Bay City, Mich., assignor to The Stalker Corporation. Provide an axial flow bladed wheel in which the blades are integral with a central disk and each blade is connected to the disk in such a manner as to minimize distortion under the action of centrifugal force acting on each blade.

CONTROL APPARATUS (2,986,126) 7 CLAIMS Wayne E. Werts, South Bend, Ind., assignor to The Bendix Corporation. A proportional acting governor with reset mechanism for controlling the governor to maintain the engine at a predetermined isochronous speed setting regardless of changes in the engine operating variables.

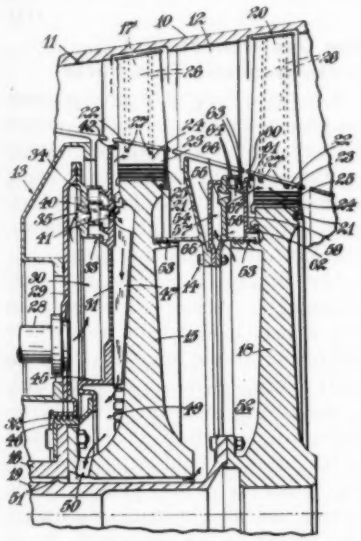
SUB-ATMOSPHERIC GAS TURBINE CIRCUITS (2,986,882) 21 CLAIMS Vladimir H. Pavlecka, Pacific Palisades, Calif. This invention relates to gas turbine power plants and more particularly to the thermodynamic cycles for gas turbine power plants operated at variable load, and the methods of operation of such plants at variable density of the working fluid in response to the variation in external load, the density of the working fluid being varied as a direct function of the external load.

FUEL NOZZLE FOR BYPASS ENGINE (2,988,878) 6 CLAIMS Philip S. Hopper, Manchester, Conn., assignor to United Aircraft Corporation, East Hart-

ford, Conn. Fuel injection apparatus comprising a fuel manifold positioned at the upstream end of a passage defining wall member, the manifold is enveloped within an airfoil-shaped ring member and carries fuel spray bars which project radially into the passage defined in part by the manifold carrying wall member to release a pattern of atomized fuel.

AFTERBURNER FUEL CONTROL HAVING MULTIPLE SETS OF NOZZLES (2,988,875) 14 CLAIMS Thomas P. Farkas, Bloomfield, Conn., assignor to United Aircraft Corporation, East Hartford, Conn. Provides a fuel control having a throttle valve for regulating fuel flow and two sets of fuel nozzles with switch-over means for further regulating the flow to at least one set of nozzles depending upon certain operating conditions.

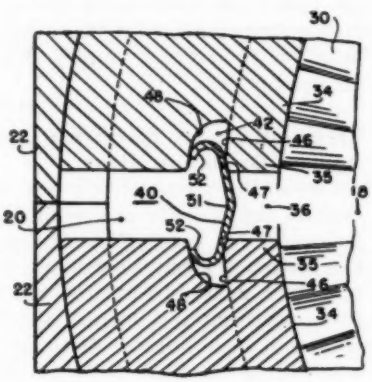
ROTARY FLUID MACHINE WITH MEANS SUPPLYING FLUID TO ROTOR BLADE PASSAGES (2,988,325) 7 CLAIMS Lindsay Grahame Dawson, Castle Donington, England, as-



signor to Rolls-Royce Limited, Derby, England. The pressure air supply includes an air supply duct 28 mounted in the stationary structure 13 and opening through a diaphragm member 29 into a manifold space 30 defined between the diaphragm 29 and an annular plate 31 mounted on the upstream face of the turbine disc 15. Excessive outflow of pressure air from the space 30 is prevented by labyrinth seal structures 32, 33 between the inner and outer radii of the plate 31 and the stationary structure 13. The pressure air flowing from the nozzles 35 across the chamber 40 and through the ports 41 divides into two streams.

FUEL CONTROL SYSTEM FOR A TWIN SPOOL GAS TURBINE POWER PLANT (2,989,849) 5 CLAIMS Bruce N. Torell and Robert E. Hull, Wethersfield, Conn., assignors to United Aircraft Corporation, East Hartford, Conn. A feature of this invention is an arrangement of a fuel control which will limit the maximum fuel flow under all operating conditions of the power plant in such a manner that even during acceleration the maximum permissible temperature will not be exceeded.

SEALING ARRANGEMENT FOR A DIVIDED TUBULAR CASING (2,991,045) 6 CLAIMS Ronald L. Tassoni, Prospect Park, Pa., assignor to Westinghouse Electric Corporation, East Pittsburgh, Pa. The present invention has been incorporated in a gas turbine including an inner casing and an outer casing of tubular shape. The inner casing defines a flow path for high temperature and high pressure gases and comprises a purity of pairs of approximately semicircular rings, interlocked one to the other and supported in a manner permitting their thermally induced expansion and contraction. The rings include terminal portions that define a pair of diametrically opposed horizontal spaces. Upon expansion the terminal portions



move toward each other, thereby reducing the width of spaces. The seal member 40 of flexible and resilient material is approximately C-shaped on cross section and supported and biased into sealing position by grooves 42 formed in the supporting rings 34. The grooves or recesses 42 are formed by an inner wall 46 having a shape conforming to that of the adjacent shroud ring and bridging ring so that a part of the wall 46 forms, with portions of the outer walls of the shroud rings and bridging rings adjacent to the space 36, continuous and longitudinally extending surfaces 47 above and below the space 36. Further, the grooves 42 are formed by an outer arcuate or approximately quarter round wall 48.

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Photographs courtesy of Lycoming Division, Avco Corp.

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GT PRODUCT TECHNICAL FILE

Instrument Drives and Controls

Literature is available from Actuator Products, Division of Geartronics Corp., describing a line of instrument drives, tachometers, flexible shafts, geared adapters, clutches and actuators. These include the actuator for the in-flight refueling system in the A3J "Vigilante" by North American Aviation, Columbus Division. The range is up through and including the APCOR 12-speed instrument drive, model 14000-S.

1133

Sikorsky HSS-2 and GE-T58

A 7-page foldout, well illustrated, tells the story of the U. S. Navy's first turbine-powered submarine hunter-killer helicopter and its General Electric powerplants. Featured in the pocket-sized brochure are summaries of the HSS-2 weapon system missions, performance, and specifications. Also described are the design features, latest performance curves, and operating experience of the turbocopter's T58 engine.

1134

T 64 Brochure

General Electric T64 Turboshaft/Turboprop, GED-4125, eight page brochure illustrates in text and photographs the four configurations of this engine described as the "versatile, reliable powerplant for the new generation of aircraft." Included is information on specifications, applications, testing programs, and availability of T64 for V/STOL, helicopter, conventional aircraft, and ground effect machines. Cutaway view, with call outs, show internal assembly sections of engine.

1135

ADEL Precision

ADEL Precision Division of General Metals Corp. has a long list of products including hydraulic motors, pumps and controls. One of their pamphlets describes the "Flapper Check Valves" handling both liquid and gas which range in temperature from —65°F to 700°F. You will find ADEL equipment not only suitable to aircraft but also various types of industrial uses.

1136

Bendix Fuel Nozzles

This brochure is designed to acquaint you with the fuel nozzle capabilities of the Eclipse Machine Division of the Bendix Corporation. Fuel metering—from relatively simple fuel pumping, through complex carburetion to the most exotic forms of fuel injection—has long been one of the major activities of this division. To quote a company officer:

"We specialize in fuel nozzles for gas turbine engines. We have contributed to many phases of the gas turbine industry and are proud to say recent jet plane speed records, both military and civilian, have been made on aircraft that employ Bendix fuel nozzles."

1137

Chromallizing as Protection Against Oxydation, Heat

Chromalloy Corporation's newest bulletin describes the process of diffusing one or more elements into the surface of steels, superalloys, or refractory metals to protect them from oxydation and thermal shock failures at high altitude. After 1800 hours of service these parts can be re-chromallized for another service-life cycle. Temperature range, depending on metals used, is from 1500°F to 3400°F.

1138

Midvac Steels Meet Most Critical Design Applications

Midvac steels, produced by the Midvale-Heppenstall Company, are offered in many alloys as billets or forgings to meet critical design specifications. Superalloys are made for reliability in temperatures of 1000°F and over. The company's products are produced by the consumable electrode vacuum arc melting process. Full details are available in a booklet offered by the company.

1139

Progress Reports by Cooper-Bessemer

The Cooper-Bessemer Corp. has issued progress reports on their RT-248 gas turbine pumping unit at Clementsville, Tenn. The RT-248 unit consists of a Pratt & Whitney Aircraft J57 used as a gas producer to drive the Cooper-Bessemer power turbine, which is coupled to the Cooper-Bessemer pipe line compressor.

1140

Marketing Information

Packaged Power Plant is title of a talk by C. W. George, Manager-Engineering, Gas Turbine Dept., of General Electric. Copies of this talk are available together with slides. It is "simply a straightforward engineering report on the characteristics of the new gas turbine package plant."

1141

New Dual-Purpose Electromagnetic Transducer

A newly designed, dual-purpose transducer which can either detect or excite vibrations without contacting the object to be tested, is being produced by Philips of the Netherlands for its sole U. S. distributor, The Korfund Company, Inc.

The Philips Type PR-9262 electromagnetic pick-up is unique in that it may be used in cases where the object to be measured has so small a mass that any contact with an indicating instrument would influence the vibration. It also permits investigation of pulsating phenomena. A feature of this pick-up is the absence of any contact resonance. The object to be measured, or vibrated, need not be magnetically conductive. By affixing a thin disc of silicon steel (furnished with the PR-9262) to the object, it is rendered effective for study by the pick-up.

Specifications are: Sensitivity—maximum of 80-millivolts/centimeter/second; Frequency response—up to 120,000-cpm, with a 15% drop-off at 60,000-cpm; Diameter—⅞ in., Length—2.0 in., Weight—1-oz.

Booklet available for the asking.

1142

Welcome to Delavan

This is one of many interesting brochures distributed by Delavan Manufacturing Company, whose principle product is fuel nozzles, many types of which are used extensively in the gas turbine field and described in their brochures.

1143

Boice Gages

A new 64-page catalog of replacement parts and spares for its high precision, dial indicator gages and setmasters is now available. To simplify ordering, contents of the book are classified by category: bore gages, bore gage setmasters, snap gages, groove gages, large diameter gages and large diameter setmasters.

1144

Briggs Filter/Separator

An engineer's manual is available describing a broad yet detailed picture of dirt contamination and separation of water from turbine fuels. The extensive illustrations, drawings and technical data should be helpful to anyone working primarily with aircraft fuel.

1145

Dynamic Balancing Machines

According to Stewart-Warner their pamphlet describes "Most-versatile-widest range 'Electronic' balancing machines in industry." This machine is portable and can be used to advantage with small gas turbines. These machines are available for all sizes and types of gas turbines.

1146

Horizontal Cooler and Condenser Catalog

Young Radiator Company has released a completely revised horizontal cooler and condenser catalog, a 16-page 2-color piece containing complete information on horizontal core air-cooled heat exchangers for temperature control and for condensing vapors. The catalog describes the efficiency and versatility of the units, contains illustrations of typical installations. The structural features of various cooling sections and available cores are illustrated and described. Design features are described, illustrated by full-page cutaway photos. Dimensional drawings and specification data complete the information offered. This is catalog #561.

1147

Contracts & Procurements

(Continued from page 10)

• Aeronautical Systems Div., (ASKPMG) WP AFB, Ohio. J85-GE-5 Turbojet Engines, iaq/Contractor's approved Engine Spec. No. E-1024B, 30 June 60, and Amend. No. 1 thereto, 26 Sept. 60; Summary Bill of Materials of Rev. thereto, and related Data. Contr. AF 33(600)-43054, 9 June 61—$1,116,000—General Electric Co., Small Aircraft Engine Dept., West Lynn, Mass.

• Directorate of Procurement and Production, Kelly AFB, Tex. Spare Parts applicable to J57-43W engine in support of B-52 aircraft AF 41(608)-14379, 24 Aug. 61 (SA-1-2915-E16678), 15 items various qtys.—$28,610—Changler Evans Corp., West Hartford, Conn.

• Cartridge, Starter Aircraft Engine, Type MXU-4/A, Contractor's P/N 300-33, and Engineering Data. (For F-105 Aircraft) Letter Contr. AF 33(657)-7032, 14 July 61, 30,000 ea.—$284,760—Olin Mathieson Chemical Corp., East Alton, Ill.

• HQ Aeronautical Systems Div., (ASKPMG) WP-AFB, Ohio. T56-A-8 Turbo-prop Engine. Supplemental Agreement N. 21, 1 June 61, to Cont. AF 33(600)41738—$93,000—General Motors Corp., Allison Div., Indianapolis, Ind.

• HQ, Mobile Air Materiel Area, USAF, Brookley AFB, Ala. Tester, Jet Cal. Circuit, related spare parts and data, AF 01(601)-36121, 1040 ea.—$124,874—Howell Instruments, Inc., Fort Worth, Tex.

• HQ, Mobile Air Materiel Area, USAF, Brookley AFB, Ala. Power wrenches and accessories used in repair and maintenance of J-60 Engines and C133 Aircraft, AF 01(601)-37297 (01-601-61-2516-Q) 308 ea.—$42,323—B. K. Sweeney Mfg. Co., Denver, Colo.

• Navy Purchasing Office, Washington, D. C. Air Turbine starter BuWeps Model A-191, (N600(19)57314 of 18 July 61) (IFB600-1129-61), qty. 400 ea.—$298,436—AiResearch Mfg. Co., The Garrett Corp., Phoenix, Ariz.

• HQS, Oklahoma City Air Materiel Area, Tinker AFB, Okla. Overhaul of J47-GE-17B/33, -25/25A and -27 Aircraft Engines. AF 34(601)-9654, 28 July 61 (RFP OC-2-2840-11, -12, -14, -15)—$2,107,840—General Electric Co., Cincinnati, Ohio.

• Aeronautical Systems Div., (ASKPMG), WP-AFB, Ohio. T58-GE-8 Gearbox Assemblies, iaw/Contractor's Main Reduction Gear Assembly Spec. No. E-1051, 1 Sept. 60. (Usage. T58-GE-8 Turboshaft Engines installed in HU2K-1 Navy Aircraft) Supplemental Agreement No. 7, 26 June 61, to Contr. AF 33(600)-42313, 36 ea.—$309,600—General Electric Co., Small Aircraft Engine Dept., West Lynn, Mass.

• HQ, San Antonio Air Materiel Area, USAF, Kelly AFB, Tex. Combustion Turbine Assembly Replacement Kit (1-130-180-01), AF 41(608)-13762, 14 Aug. 61 (SA-1-2840-E16444), 17 ea.—$251,241—AVCO Corp., Lycoming Div., Stratford, Conn.

• Aeronautical Systems Div., (ASKPMG) WP-AFB, Ohio. J69-T-25 Engines iaw/Contractor's Model Spec. #2149, 26 May 58, incorp. herein by reference with Government Furnished Fuel Controls modified to P/N 626184-7 in lieu of Contractor Furnished Fuel Controls. (Spares for Support of T-37B Aircraft) Supplemental Agreement No. 9, 19 July 61, to Contr. AF 33(600)-42426—$129,573—Continental Aviation and Engineering Corp., Toledo, Ohio.

• Aeronautical Systems Div. (ASKPMG), WP-AFB, Ohio. J79-GE-11A Turbojet Aircraft Engines with afterburner and Related Data for F-104 Aircraft. Supplemental Agreement No. 5, 17 May 61, to Contract AF 33(600)-42639—$564,945—General Electric Co., Flight Propulsion Div., Cincinnati, Ohio.

• HQ, Aeronautical Systems Div., (ASKPMG-1) WP-AFB, Ohio. Starters, Pneumatic, Aircraft Engine. USAF Type STU 1/A; Spare Parts, Aerospace Ground Equipment and Data. (Installations and Spares for USAF and Navy C-130B Aircraft) Letter Contract AF 33-(600)42854, 9 Mar. 61, 212 ea.—$103,801—The Garrett Corp., AiResearch Mfg. Co., Phoenix, Ariz.

• Dept. of the Navy, Bu. Naval Weapons, Washington, D. C. 4 GTP 30-203 Gas Turbine Power Units in accordance with Contractor's Drawing 379003-3. NOw 61-1038-f—$38,000—The Garrett Corp., AiResearch Mfg. Co., Phoenix, Ariz.

Allison T63

An attractive little brochure has been issued to describe the T63, complete with its ratings and applications. The free turbine unit is compact, weighs less than 130-lbs.

1148

Lycoming T53 & T55

Specification sheets are available on the various models of the T53 and T55 free power turbines, as well as a 4-page brochure describing "Helicopter Engines by Lycoming."

1149

INDUSTRY NEWS . . .

Boeing New Ground Support Unit Passes Air Force Test

The United States Air Force has completed review of the results of a recent company-sponsored endurance test of Boeing's latest gas turbine-driven compressor, 502-11BA.

The endurance and cycling tests were run by Boeing to military specifications covering ground support equipment. The two engines were torn down and inspected by both Boeing and United States Air Force personnel. Boeing engineers commented that the engines were "in excellent condition" and Boeing is considering plans to continue running the units beyond the 5000 start-stop and 500-hour marks to establish the life of the engine and its accessories.

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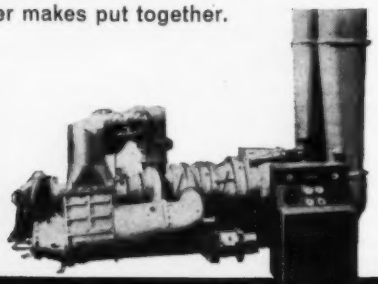
DAILY NEWS
SEPTEMBER 23 1961

NO TROUBLE IN KUWAIT... OR LITTLE ROCK

In sunbaked Kuwait two Ruston 'TA' industrial gas turbines have each been pumping oil for more than 21,000 hours since their last overhaul—and this total is still rising. At the modern Park Plaza shopping centre in Little Rock, Arkansas, another 'TA' is producing all the electrical power, the summer and winter air conditioning, *and* the hot water . . . faultlessly.

All over the world more Ruston industrial gas turbines are in operation in the 1000-2000 b.h.p. bracket than all other makes put together.



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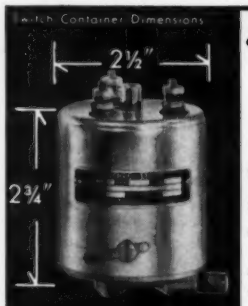
Switch Container Dimensions



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